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ANNUAL ENVIRONMENTAL MONITORING REPORT
U. S. DEPARTMENT OF ENERGY, ROCKY FLATS PLANT

January Through December 1987

ENVIRONMENTAL MANAGEMENT SECTION

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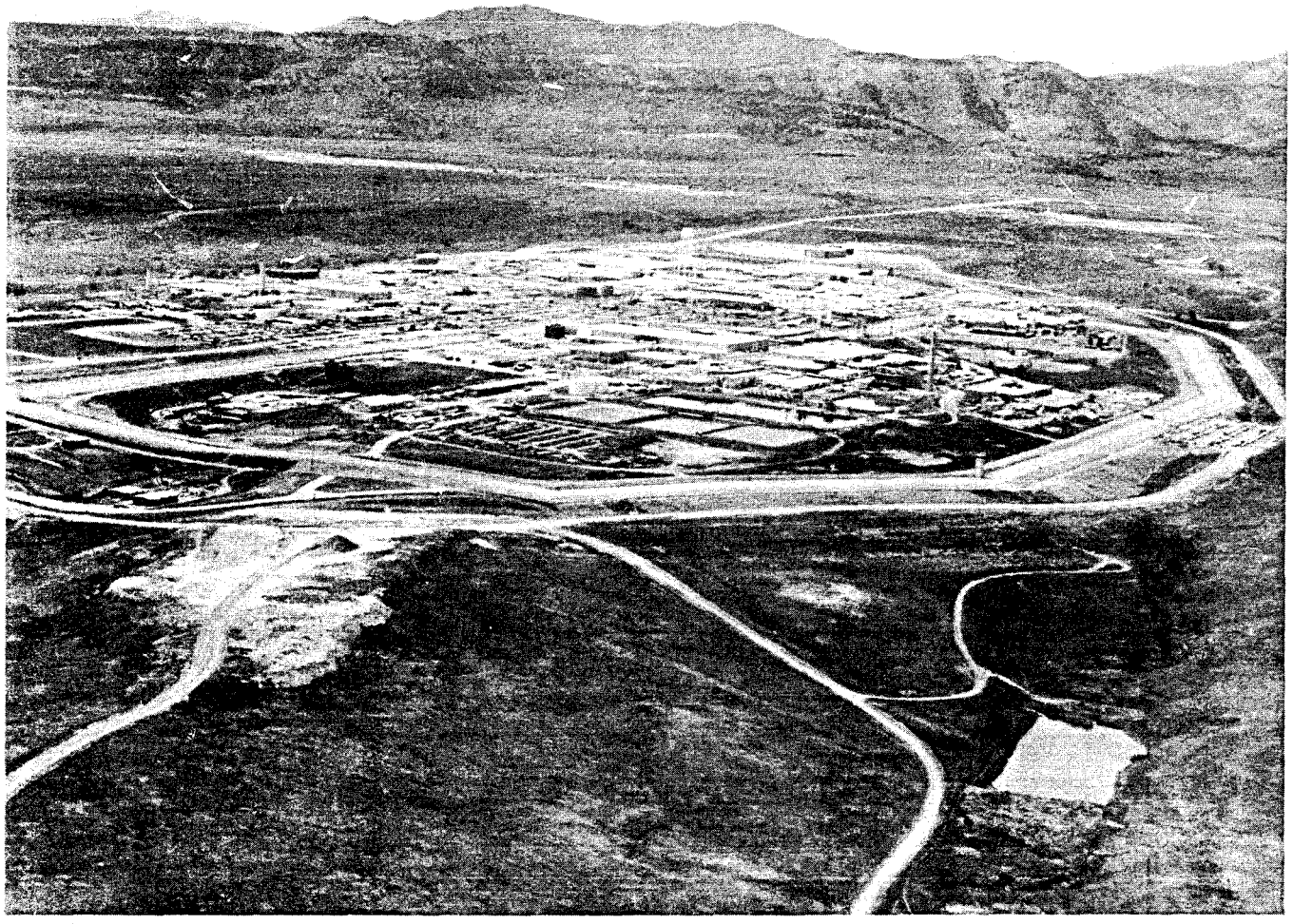

ROCKY FLATS PLANT VIEWED FROM THE EAST 33323-10

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ABSTRACT

This report documents the environmental surveillance program at the Rocky Flats Plant, as conducted by the Environmental Management Section of the Health, Safety and Environment (HS&E) Operations Management Branch under the operating contractor, Rockwell International, Aerospace Operations Group. Sample analyses are performed by the Health/Environment Analytical Laboratories (H/EL) of the Health, Safety and Environment Department and by the General Laboratory of the Quality Engineering and Control Department. The report includes an evaluation of plant compliance with all appropriate guides, limits, and standards. Potential public radiation dose commitments were calculated from average radionuclide concentrations measured at the plant property boundary and in surrounding communities. The radioactive and non-radioactive effluents from the Rocky Flats Plant meet the appropriate guides and standards and represent no measurable adverse environmental effects from the operation of the plant during calendar year 1987. The estimated potential radiation doses to the public from plant effluents are below Department of Energy and Environmental Protection Agency dose standards and are well below background dose levels experienced in this region from natural and other non-Rocky Flats Plant sources.

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I. INTRODUCTION

The Rocky Flats Plant is a government-owned and contractor-operated facility. It is part of a nationwide nuclear weapons research, development, and production complex administered by the Albuquerque Operations Office of the U. S. Department of Energy (DOE). The prime operating contractor for the Rocky Flats Plant is the Aerospace Operations Group of Rockwell International.

The Rocky Flats Plant is located at 105°11'30" west longitude and 39°53'30" north latitude in northern Jefferson County, Colorado. The plantsite consists of 2,650 hectares (6,550 acres) of federally owned land. As shown in Figure 1, major plant structures are located within a security-fenced area of 155 hectares (384 acres). The plant is approximately 26 kilometers (16 miles) northwest of downtown Denver and is almost equidistant from the cities of Boulder, Golden, and Arvada (see Figure 2). Demographic estimates for 1980 are shown in Figure 3. There is a population of approximately 2 million people within a 50-mile radius of the plant.

The plant is a key DOE facility that produces components for nuclear weapons; therefore, its product is directly related to national defense. The plant is involved in fabricating components from plutonium, uranium, beryllium, and stainless steel. Production activities include metal fabrication and assembly, chemical recovery and purification of process-produced transuranic radionuclides, and related quality control functions. Research and engineering programs supporting these activities involve chemistry, physics, materials technology, ecology, nuclear safety, and mechanical engineering.

Approximately 136 structures on the plantsite contain approximately 249,000 square meters (2.68 million square feet) of floor space. Of this space, major manufacturing, chemical processing, plutonium recovery, and waste treatment facilities occupy about 148,600 square meters (1.6 million square feet).

The remaining floor space is divided among laboratories, administrative, utility, security, warehouse, storage, and construction contractor facilities, and occupies about 100,300 square meters (1.08 million square feet).

All of the plant heating requirements are met by in-plant steam boilers that normally use natural gas and are capable of using fuel oil. During CY 1987, approximately 16.3 million cubic meters (574 million cubic feet) of natural gas were used. Approximately 4,900,000 liters (1,300,000 gallons) of fuel oil were used during 1987.

Raw water is purchased from the Denver Water Board and is drawn from Ralston Reservoir and the South Boulder Diversion Canal. The Rocky Flats Plant used approximately 454 million liters (120 million gallons) of water during 1987.

The piedmont of the Front Range of the Rocky Mountains rises 8 kilometers (5 miles) west of the site and crests at the Continental Divide, which is 32 kilometers (20 miles) from the plant. The natural environment of the plantsite and vicinity is influenced primarily by the Front Range of the Rocky Mountains and the site elevation, which is 1,829 meters (6,000 feet) above sea level. The surficial geology of Rocky Flats consists of a thin layer of gravelly fine-textured topsoil underlain by a 6- to 15-meter (20- to 49-foot) thick layer of coarser, clayey gravel. This is underlain by a bedrock structure upon which plant building foundations are supported. Area hydrology is influenced by the surficial materials, which consist of gravelly but slowly permeable alluvium. The vegetation of the area consists of species representative of the short- and mid-grass prairie; primarily grasses, cacti and broom snakeweed.

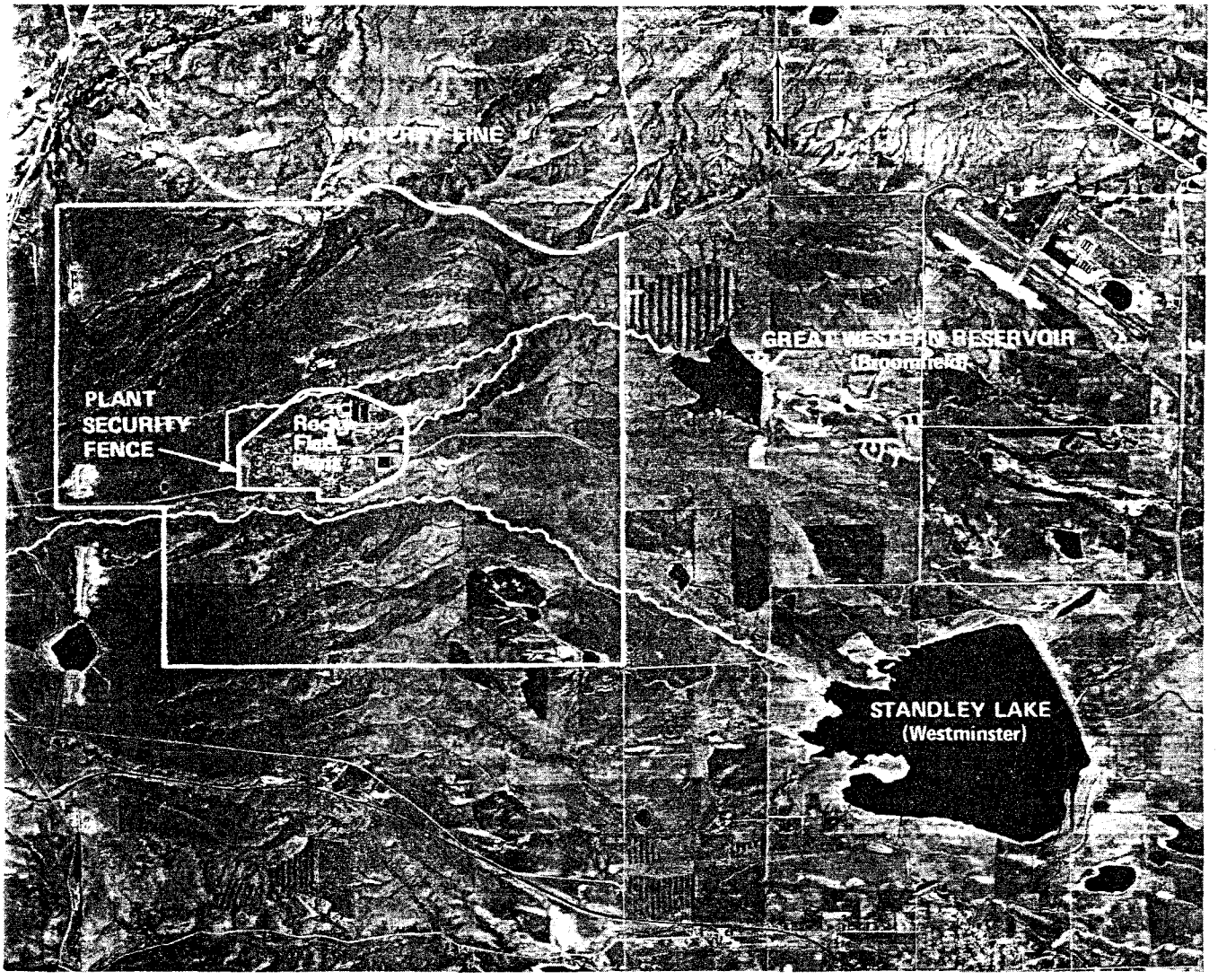


FIGURE 1. Aerial Photograph of the Rocky Flats Plant and Immediate Vicinity 15299

Introduced Eurasian weeds also make up part of the flora and riparian vegetation exists along the watercourses.

The climate at Rocky Flats is characterized by dry, cool winters with some snow cover and warm, somewhat moist summers. There is considerable clear-sky sunshine, and the average precipitation and relative humidity are low. The elevation of the plant and the major topographical features of the area significantly influence the climate and meteorological dispersion characteristics of the site.

Winds at Rocky Flats, although variable, are predominantly northwesterly, with stronger winds occurring during the winter. During 1987, approximately 56 percent of the winds had a westerly component.

Annual average precipitation at the Rocky Flats Plant is slightly over 38.5 centimeters (15.16 inches). The maximum annual precipitation recorded over a 24-year period was 63.17 centimeters (24.87 inches) in 1969. Typically, more than 80 percent of the precipitation falls as rain

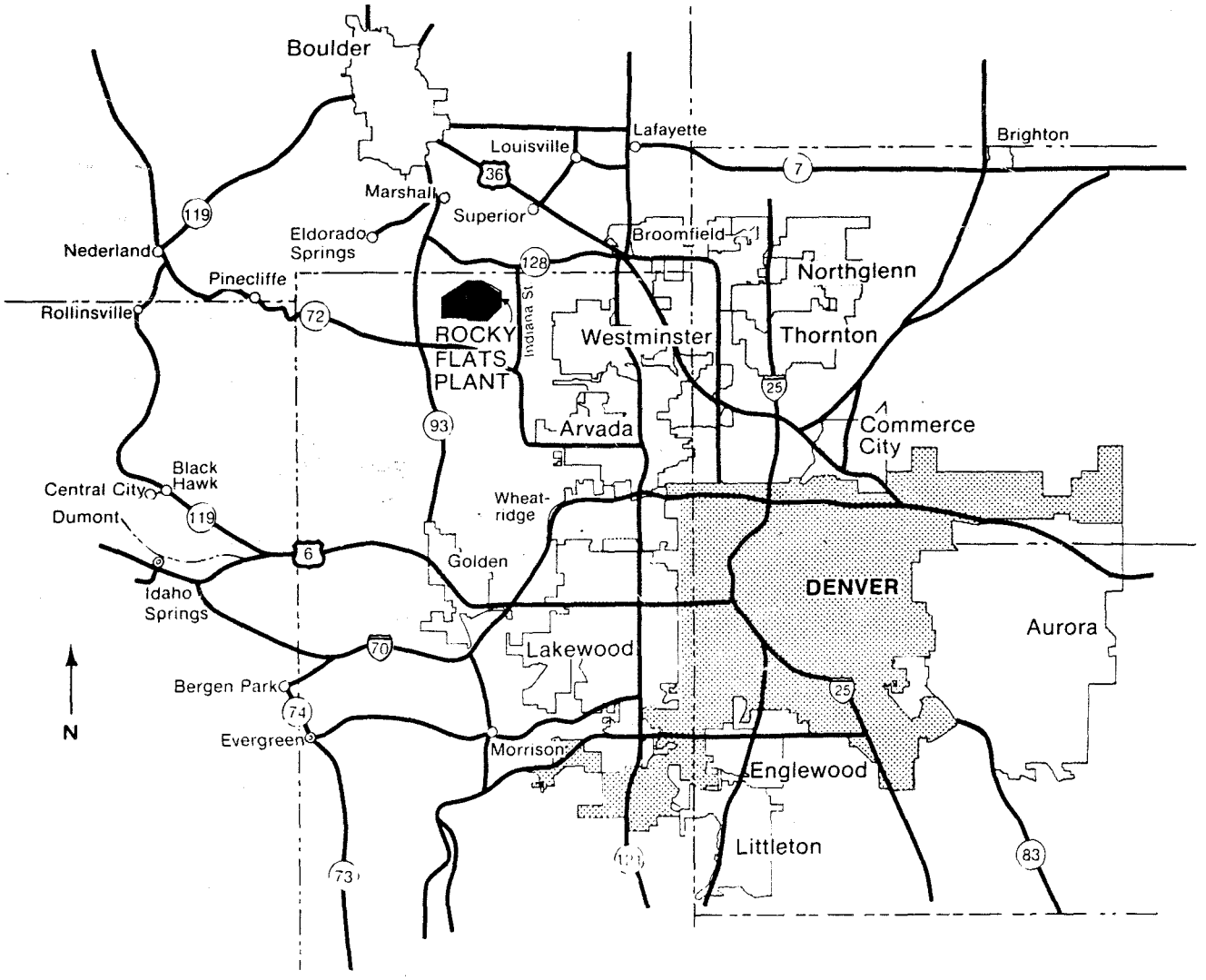


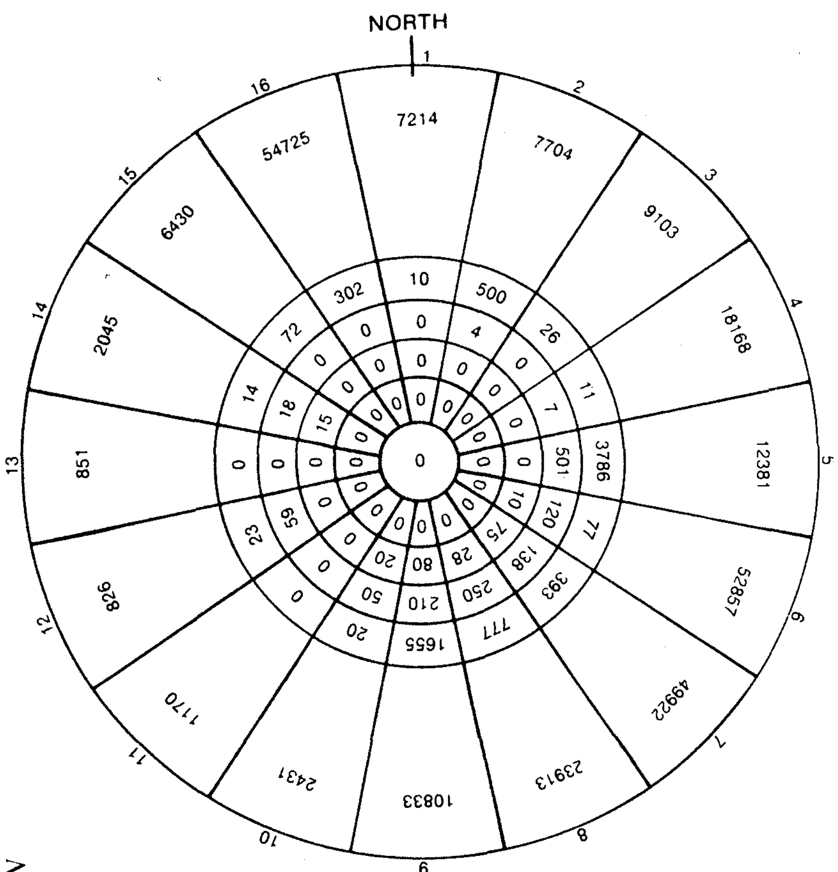
FIGURE 2. Area Map of Rocky Flats Plant and Surrounding Communities

between April and September. Most of the remaining precipitation is in the form of snow. In 1987, The Rocky Flats Plant recorded 40.85 cm (16.08 inches) of precipitation.

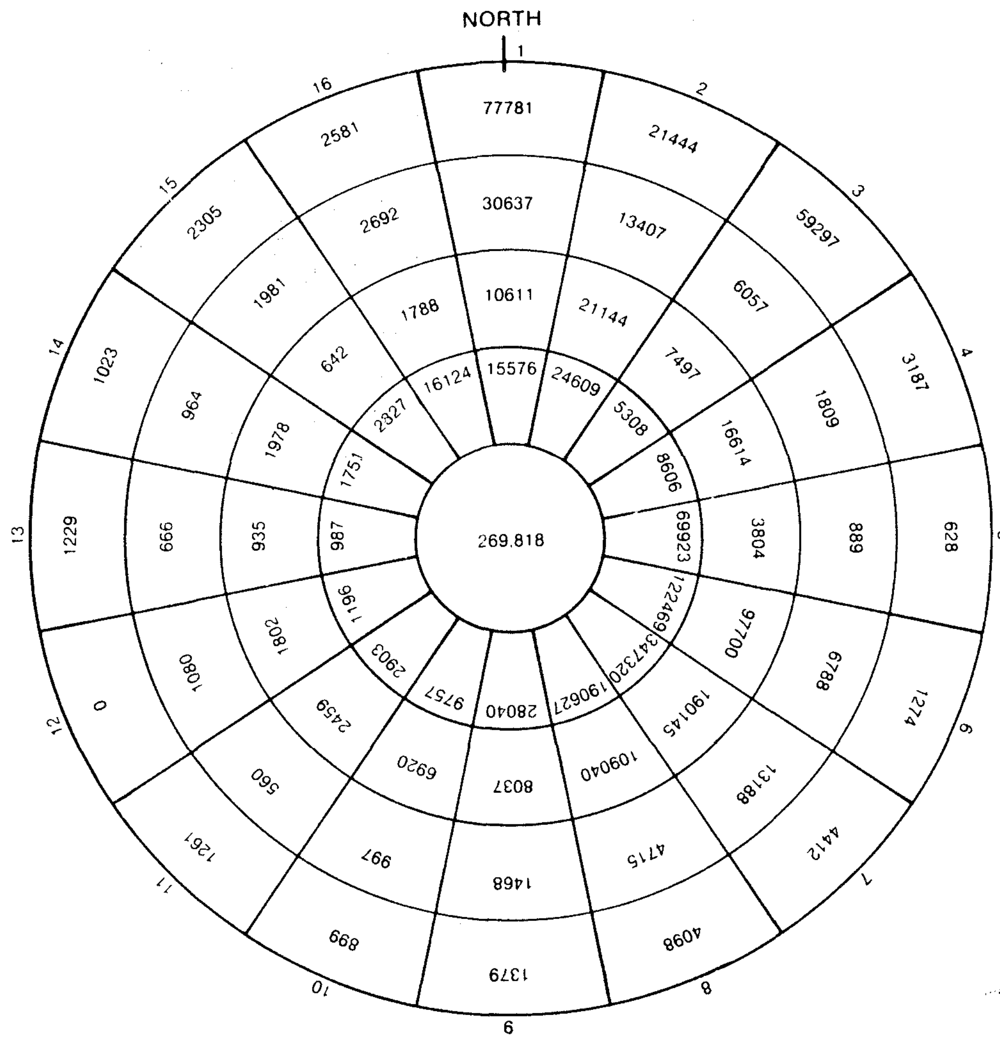
Air from production and research facilities is continuously discharged to the atmosphere by 50 ventilation exhaust systems. Prior to atmospheric discharge, the exhaust air passes through particulate filtration systems located in filter plenums. These filtration systems employ High Efficiency Particulate Air (HEPA) filters, that are purchased to equal or exceed the DOE specified filtration efficiency standard of 99.97 percent for 0.3-μm particles. Prior to installation in the filter plenums each filter is tested at the plant to ensure that the filtration efficiency is not less than the standard. Once installed filters are tested for leaks which might have developed during handling and installation. Leaking filters are replaced and the system retested. Airborne radioactivity released to the environment from process operations is kept to a minimum and is well within plant health and safety guidelines.

As shown in Figure 4, surface water runoff from the plant generally is from west to east. Runoff is carried from the plant by three major drainage

FIGURE 3. Demographic Estimates - 1980[a]



0-16 Kilometers (0-10 miles) From Rocky Flats[b]



16-80 Kilometers (10-50 miles) From Rocky Flats[c]

a. These population estimates (0-16 kilometers) were calculated from 1980 Census Tract Data, assuming even population distribution throughout the sector.
b. Concentric circles represent 1-to-2, 2-to-3, 3-to-4, 4-to-5, and 5-to-10-mile mileage bands.
c. Concentric circles represent 10-to-20, 20-to-30, 30-to-40, and 40-to-50-mile mileage bands.

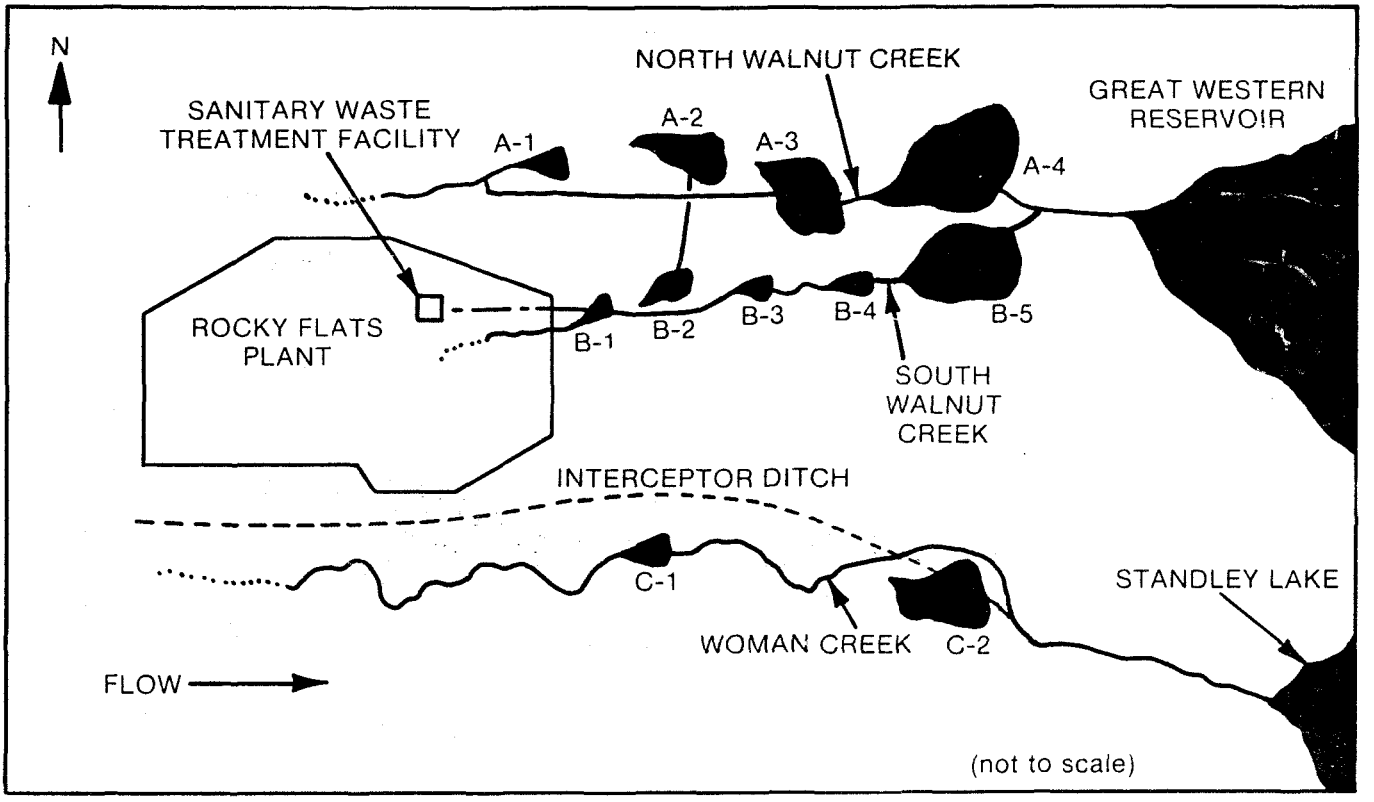


FIGURE 4. Holding Ponds and Liquid Effluent Watercourses

basins that are tributaries to Walnut Creek on the north and to Woman Creek on the south. The south fork of Walnut Creek receives most of the stormwater runoff from areas surrounding plant buildings.

Also shown in Figures 1 and 4 is the confluence of the north and south forks of Walnut Creek which is 1.1 kilometers (0.7 miles) west of the eastern perimeter of the plant. Great Western Reservoir, a water supply for a part of the City of Broomfield, is 1.6 kilometers (1 mile) east of this confluence. Woman Creek flows east from Rocky Flats into Standley Lake, a water supply for the City of Westminster and for portions of the cities of Northglenn and Thornton. Ponds on the north fork of Walnut Creek are designated A-1 through A-4. Ponds on the south fork are designated B-1 through B-5. These A- and B-series ponds receive runoff and/or treated sanitary wastewater. Pond C-1 is located on the Woman Creek watercourse and receives only undisturbed natural flows. Pond C-2, located near the Woman Creek watercourse, receives surface runoff water from an interceptor ditch parallel to the south side of the plant production areas.

Certain operations at the Rocky Flats Plant involve or produce liquids, solids, and gases containing radioactive materials. Radioactive materials are handled in accordance with stringent procedures and within multiple containments (physical barriers) designed to minimize the release of contaminants to the workplace and the environment. Processing activities include the incineration of plutonium-contaminated materials for recovery of the plutonium that they contain. This recovery operation is in accordance with an incineration permit issued to the plant by the Colorado Department of Health. The radioactive waste systems include collection, filtration, liquid processing, and temporary storage facilities for those process wastes known, or suspected, to have been in contact with radioactive materials. The liquid waste process system concentrates the contamination from liquid waste into solid wastes suitable for shipment, along with other contaminated solid wastes, to a DOE-approved storage facility.

Specific details of plant waste processing facilities are described in the Rocky Flats Plant Site Final Environmental Impact Statement.(US80a)

Sanitary waste is processed by the sanitary wastewater treatment plant, and is isolated from process waste throughout the plant. Conditioning chemicals are added to improve flocculation and filtration of suspended solids. The treatment plant is of the activated sludge type and has three stages of treatment. It has a design capacity of 946,330 liters (250,000 gallons) per day. Present daily flows usually vary between 757,000 and 1,135,600 liters (200,000 and 300,000 gallons) per day. One of two 265,000-liter (70,000 gallon) preaeration holding tanks, located upstream from the sewage plant, serves as a surge basin to smooth out peak flows. A second holding tank provides storage capacity for sanitary wastes should emergency retention be required. Liquid effluents from the sanitary waste treatment plant are released to holding bonds for subsequent use in onsite irrigation or offsite discharge to Walnut Creek, or they may be pumped to a reverse osmosis facility for further treatment. After treatment, product water from the reverse osmosis facility can be recycled for use in plant cooling towers, spray irrigation, or may be released to Walnut Creek. The plant has a zero discharge goal with respect to downstream discharges. Such discharges occur only when weather conditions prevent effective spray irrigation activities.

Residual solids from the sanitary waste treatment plant are concentrated, dried, packaged, and shipped to a DOE-approved waste facility. Reverse osmosis brine is sent to process waste treatment for evaporation and drying, and the salts are packaged and shipped to a DOE-approved storage facility.

In 1987, solid wastes that had no radioactive or hazardous chemical constituents were transferred to an onsite sanitary landfill for disposal. This landfill was designed and constructed in 1974 with an impervious clay seal layer, a groundwater intercept system, and surface water diversion ditches to isolate the landfill from the general environment. Routine waste materials are checked daily for radioactivity at the landfill site before final burial. In addition, routine waste materials originating from buildings in which radioactive materials are handled are monitored prior to leaving the building to ensure that they are free from radioactive contamination. The disposal of nonroutine or special non-radioactive waste materials is administratively controlled.

Groundwater and surface water flow in and around the sanitary landfill is controlled by interceptor ditches and by french drains. The ditches divert all upgradient surface waters around the landfill. The drains collect groundwater from the perimeter of the landfill and divert it around the landfill. The holding pond collects surface and subsurface drainage from the landfill. Water samples from this holding pond, the drains, and from six (as of 1987) RCRA-quality groundwater monitoring wells in the vicinity are collected routinely and are analyzed for a series of parameters including radioactivity.

Land use at the Rocky Flats Plant is managed by Rockwell International for the Department of Energy. This includes land utilization planning and environmental and physical control of the land. Since 1977, all major activities conducted on plantsite land require approval by the Rockwell Executive Committee based upon the recommendations of the Land Management Coordinator. The Coordinator evaluates all research projects and other nonroutine activities on plant lands by means of a Land Use Request system. The effects of such activities are evaluated by Environmental Management personnel through field observations and remote sensing techniques.

Personnel in the Environmental Management Group of Rockwell International conduct an extensive environmental control and surveillance program at the plant. The surveillance program is designed to provide assurance that the many safeguards at the plant effectively limit the release of radioactive or toxic materials. The results of this environmental monitoring program indicate that effluent treatment and control processes at the plant were effective during 1987.

The Rocky Flats environs are monitored for penetrating ionizing radiation and for pertinent radioactive, chemical, and biological pollutants. Air, water, and soil are sampled on the plantsite and

throughout the surrounding region. Several Federal, State, and local governmental agencies independently conduct audits and additional environmental surveys both on and off the plant-site. The Colorado Department of Health samples air, soil, and water at the Rocky Flats site and in surrounding communities. The DOE Environmental Measurements Laboratory (EML) has conducted particulate air sampling at the Rocky Flats Plant and has periodically performed special studies, including sediment and soil analyses. Additional special analyses have been performed by Region VIII of the U. S. Environmental Protection Agency (EPA).

Plutonium concentrations in this report represent the alpha radioactivity from plutonium isotopes 239 and 240, which constitute over 97 percent of the alpha radioactivity in plutonium handled at the the plant. Reported uranium concentrations are the cumulative alpha activity from uranium-233, -234, and -238. Components containing fully enriched uranium are handled at the Rocky Flats Plant. Depleted uranium metal is fabricated and also is handled as process waste material. Uranium-235 is the major isotope by weight (93 percent) in fully enriched uranium; however, uranium-234 accounts for approximately 97 percent of the alpha activity of fully enriched uranium. In depleted uranium, the combined alpha activity from uranium-234 and -238 accounts for approximately 99 percent of the total alpha activity.

The Derived Concentration Guides (DCGs) used in this report for uranium in air and water are those for uranium-233, -234, and -238, which are the most restrictive.*

The information contained in this report is submitted in compliance with DOE Order 5484.1, Chapters III and IV, and is a compilation of data provided monthly to the DOE Rocky Flats Area Office, the Radiation Control Division of the Colorado Department of Health, Region VIII of the EPA, the health departments of Boulder and Jefferson Counties, and to interested city officials and citizens from communities near the plant.

*The Derived Concentration Guides used throughout this report were calculated using the methodology described in Appendix A.

II. SITE METEOROLOGY AND CLIMATOLOGY

Wind, temperature and precipitation data were collected on the plantsite during 1987. Table 1 is the 1987 annual summary of the percent frequency of wind directions (16 compass points) divided into four speed categories. Due to data recording problems, wind data for May of 1987 was unavailable. Wind data from May of 1986 was substituted to provide a representative annual sample. The compass point designations indicate the true bearing when facing against the wind. These frequency values are represented graphically in Figure 5. The wind rose vectors also represent the bearing against the wind (i.e., wind along each vector blows toward the center). The predominance of northwesterly winds is typical of the Rocky Flats Plant. More calm periods were recorded in 1987 than is usual for the area. The low frequency of winds greater than 7 meters per second (15.6 mph) with easterly components is also normal.

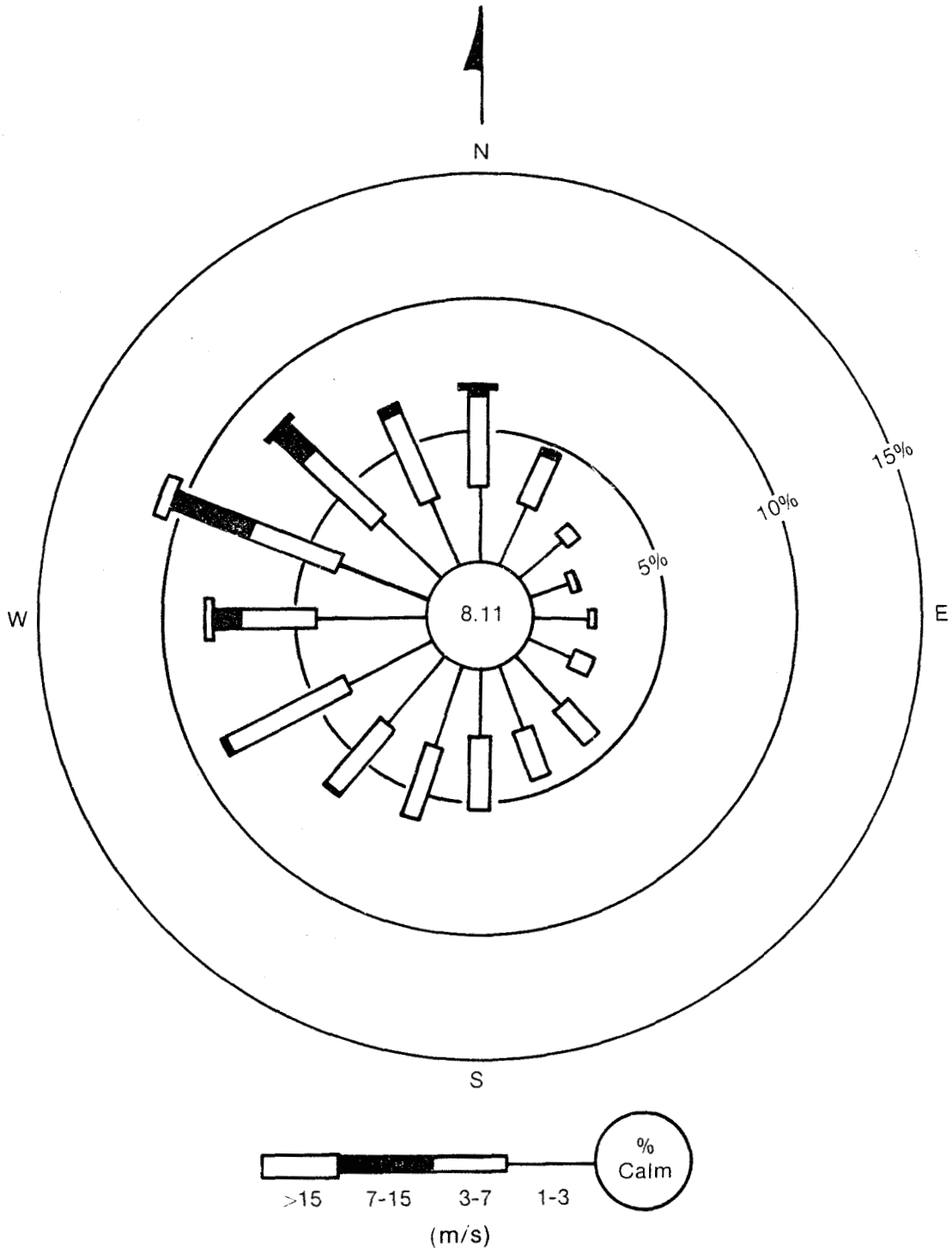
TABLE 1. Wind Direction Frequency (Percent), by Four Wind-Speed Classes, at the Rocky Flats Plant[a]

(Fifteen-Minute Averages–1987[b])

	Calm	1-3 (m/s)[c]	3-7 (m/s)	7-15 (m/s)	>15 (m/s)	TOTAL
-	8.11	-	-	-	-	8.11
N	-	2.71	3.61	0.50	0.01	6.82
NNE	-	2.55	1.97	0.19	0.00	4.72
NE	-	1.84	0.75	0.02	0.00	2.62
ENE	-	1.44	0.26	0.00	0.00	1.70
E	-	1.99	0.20	0.01	0.00	2.19
ESE	-	1.91	0.83	0.01	0.00	2.75
SE	-	2.62	1.72	0.02	0.00	4.37
SSE	-	2.49	2.02	0.13	0.00	4.64
S	-	2.52	2.63	0.19	0.00	5.34
SSW	-	3.05	3.00	0.19	0.00	6.25
SW	-	3.43	3.32	0.12	0.00	6.86
WSW	-	3.74	4.85	0.35	0.00	8.94
W	-	4.31	2.95	0.96	0.15	8.38
WNW	-	3.67	3.65	3.19	0.38	10.89
NW	-	3.17	3.77	1.41	0.01	8.37
NNW	-	2.82	3.66	0.24	0.00	6.72
TOTALS	8.11	44.26	39.20	7.54	0.56	100.00

a. May data taken from 1986 due to data recording failure in May 1987.
b. Data obtained from sensors located 10 m (33 ft) above the ground.
c. For conversion purposes, miles per hour (mph) equals 2.237 multiplied by meters per second (m/s).

FIGURE 5. 1987 Annual Wind Rose for the Rocky Flats Plant



The mean temperature recorded for 1987 was 10.1 °C (50.8 °F).

Based on 24-year monthly water-equivalent precipitation averages, collected between 1953 and 1976, the mean annual precipitation at the Rocky Flats Plant is 38.50 centimeters (15.16 inches). In 1987, the Rocky Flats Plant recorded 40.85 centimeters (16.08 inches) of precipitation.

III. MONITORING SUMMARY

During 1987, the Rocky Flats Plant conducted an environmental monitoring program that included the sampling and analysis of airborne effluents, ambient air, surface and ground water, and soil. External penetrating gamma radiation exposures were also measured using thermoluminescent dosimeters. The monitoring program consists of collecting samples from onsite, boundary, and offsite locations. Monitoring of water for trace quantities of toxic materials, metals, nitrates, anions, volatile organic compounds (VOCs), and specific radionuclides also was performed. Specific details of the routine Rocky Flats Plant Environmental Monitoring Program are documented in the "Catalogue of Monitoring Activities at Rocky Flats."(Se86)

Several environmental permits have been issued to the plant by Federal and State agencies. Currently, the following permits are in "Active" status:

> National Pollutant Discharge Elimination System Permit CO-0001333; issued by the U. S. Environmental Protection Agency, December 26, 1984.
>
> Building 122 Incinerator Permit C-12, 931; issued by the Colorado Department of Health, March 25, 1982.
>
> Building 771 Incinerator Permit 12JE932 (C-12, 932); issued by the Colorado Department of Health, August 28, 1985.
>
> Building 776 Fluid Bed Incinerator Permit C-13, 022; issued by the Colorado Department of Health, March 25, 1982.
>
> Fugitive Dust Emission Permit 87JE052L for remedial action program, issued by the Colorado Department of Health on June 15, 1987.

On July 31, 1986, a Compliance Agreement was entered into by the Environmental Protection Agency (EPA), the Colorado Department of Health (CDH), and the Department of Energy (DOE) for implementation and regulation of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) activities for the Rocky Flats Plant. On November 26, 1986, the Rocky Flats Plant submitted a RCRA Part B Permit Application to EPA and CDH. The RCRA Part B Permit Application was revised in accordance with comments received from EPA and CDH and resubmitted on December 15, 1987. The submittal of draft Remedial Investigation reports on July 1 and December 31, 1987, also took place in accordance with the Compliance Agreement. The RCRA Part B Permit Application and other Compliance Agreement reports currently are undergoing EPA and CDH review.

Particulate and tritium sampling of building exhaust systems was conducted continuously in 1987. Overall, 1987 emission data were in the ranges projected in the Plant Environmental Impact Statement(US80a) and presented no significant environmental impact.

Particulate samples are collected from ambient air samplers operated continuously onsite, at the plant perimeter, and in fourteen community locations. Analysis of these samples indicated that the concentrations of airborne plutonium at all locations were far below applicable Derived Concentration Guides (DCGs). (See Appendix A.) At the plant perimeter and at the community locations, the 1987 average plutonium concentrations in ambient air at each location were 0.13 percent or less of the DOE interim standard DCGs.

During 1987, monitoring of ambient air for total suspended particulates (TSP), ozone (O_3), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), and lead (Pb) was conducted.

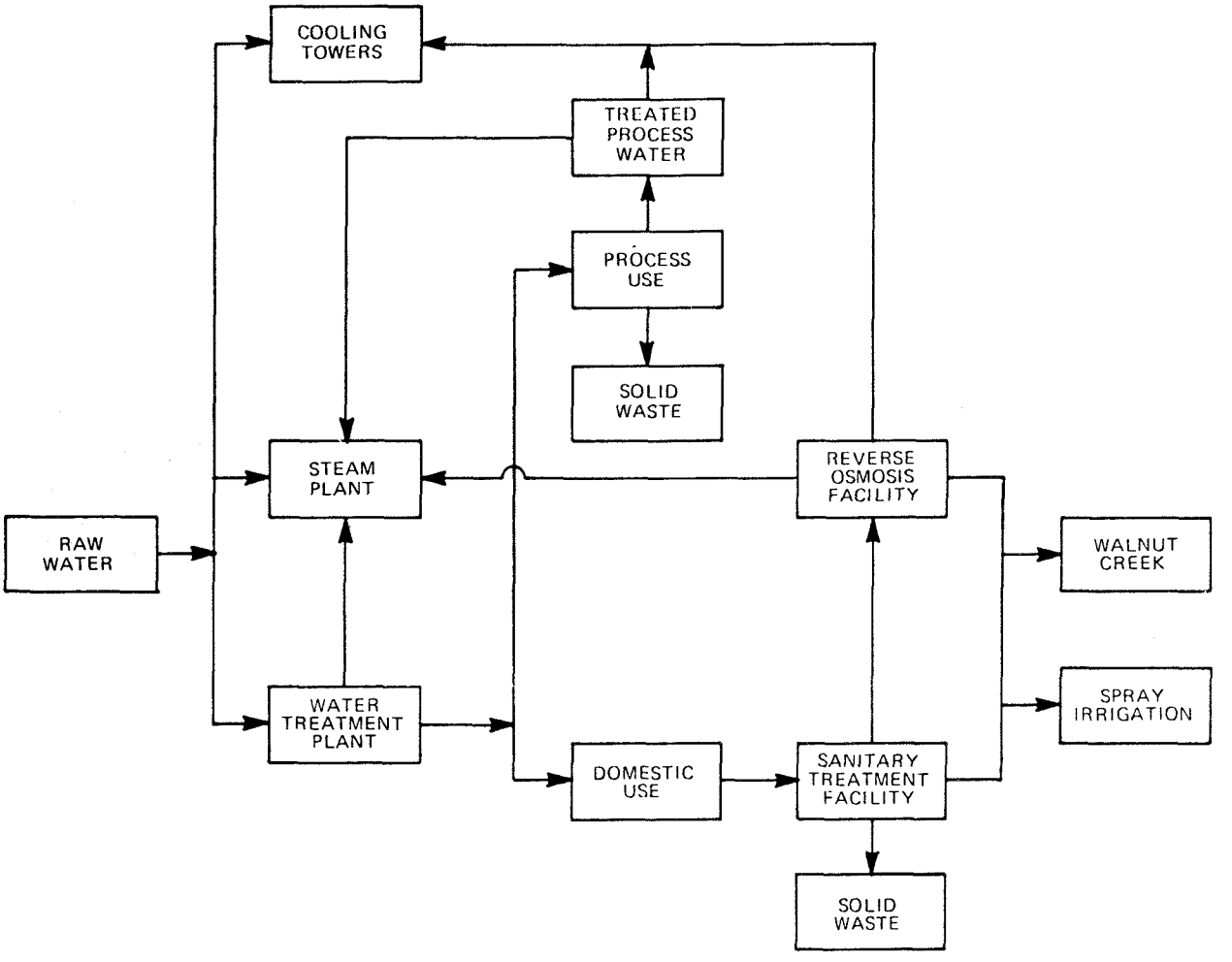


FIGURE 6. Water Use at the Rocky Flats Plant

These six parameters are criteria pollutants regulated by the EPA and the State of Colorado through the Clean Air Act of 1970 that includes the National Ambient Air Quality Standards (NAAQS).(US81b) The 1987 calculated annual geometric mean for TSP was 55 percent of the primary annual geometric mean standard prescribed by the NAAQS. The highest one-hour concentration of O_3 in 1987 was 112 percent of the EPA primary one-hour standard. This value was consistent with levels reported in the Denver Metropolitan area at that time. The 1987 annual arithmetic mean for SO_2 was 4 percent of the EPA primary annual arithmetic mean 3-hour standard. The highest recorded 1-hour SO_2 reading was 0.025 ppm. The annual arithmetic mean of the NO_2 concentrations for 1987 was 10 percent of the EPA primary annual arithmetic mean standard. The quarterly lead concentrations measured during 1987 were less than three percent of the EPA quarterly standard.

The majority of the water used during 1987 for plant process operations and sanitary purposes was treated and evaporated and/or reused for cooling tower makeup, steam plant use, or for spray irrigation within the plant boundaries. A schematic diagram of water use is shown in Figure 6.

Surface runoff from precipitation is collected in surface water control ponds. After monitoring, this water is discharged offsite. Those discharges are monitored for compliance with an EPA National Pollutant Discharge Elimination System (NPDES) permit.(US84a) During 1987, the Rocky

Flats Plant had two violations of its NPDES permit. Both were technical violations not related to the plant sanitary wastewater treatment operations. A discussion of these violations appears in Section IV. D.

Routine water monitoring is conducted for two downstream reservoirs and for drinking water sources in nine communities. The average radioactivity concentrations for plutonium, uranium, americium, and tritium measured at these locations were found to be 0.7 percent of less of the DCGs for water. (See Appendix A.) The sum of the average concentrations for plutonium and americium in drinking water samples for each community was 0.1 percent or less of the State of Colorado regulations for alpha-emitting radionuclides(Co81) and the EPA National Interim Primary Drinking Water Regulations.(US76a) Average concentrations of tritium in community drinking water samples were all within local background range and were 3.5 percent or less of the applicable State of Colorado and EPA drinking water standards.(Co81, US76a)

As part of the Rocky Flats RCRA/CERCLA Compliance Agreement signed July 31, 1986, extensive hydrologic, geologic and groundwater quality investigations continued through 1987. Initial investigations indicate above background concentrations of some radioactive and chemically hazardous materials within close proximity to past plant disposal sites and plant operations. These materials include volatile organic compounds and some radionuclides.

Remedial Investigation (RI) activities, an outgrowth of the Compliance Agreement, required the completion of 46 additional monitoring wells during 1987. These new wells will assist in the delineation of radioactive or hazardous chemical constituents in designated high priority investigation areas, and they become part of an extensive plantwide groundwater monitoring system. Corrective action measures for areas are now under evaluation. Monitoring wells also were installed near previously-used solar evaporation ponds (4 wells) and the present landfill (17 wells) as part of the RCRA Closure Permit. A total of 159 onsite groundwater monitoring wells are now monitored quarterly.

A vegetation control program using chemical herbicides was conducted during 1987. The program was completed by independent licensed contractors using EPA approved chemicals according to the requirements of the labels. Onsite storage of pesticides and herbicides at the Rocky Flats Plant currently is being discontinued.

Surface soil samples for plutonium analysis were collected in 1987 from 40 sites located on radii from Rocky Flats Plant at distances of 1.6 and 3.2 kilometers (1 and 2 miles). The purpose of the program was to determine if there are any changes in plutonium concentrations in the soil around the plant over time. This program was conducted intermittently until 1977 and reinitiated during 1984. The 1987 plutonium concentrations in the 3.2 kilometer samples, which are near the plant boundary, were in the range from 0.03 to 4.48 pCi/g (1.11 to 166 Bq/kg). Plutonium concentrations for 1987 at a 1.6 kilometer radius ranged from 0.03 to 7.05 pCi/g (1.11 to 261 Bq/kg). These levels are similar to the soil data reported in 1977 and 1986.

The 1987 environmental measurement of external penetrating gamma radiation, using thermoluminescent dosimeters (TLDs), showed that the annual dose equivalent onsite, at the plant perimeter, and at community locations was within the range of regional background.

Potential public radiation dose commitments, which could have resulted from plant operations, were calculated from average radionuclide concentrations measured at the Rocky Flats Plant property boundaries and in surrounding communities. Dose assessment for 1987 was conducted for the property (site) boundary, nearby communities, and to a distance of 80 kilometers (50 miles). At the plant boundary, the maximum 50-year dose commitment to an individual was calculated to be 6.6×10^{-4} rem (6.6×10^{-6} Sv*) effective dose equivalent and 1.1×10^{-2} rem (1.1×10^{-4} Sv) to bone surfaces. By comparison, annual effective dose equivalent from the natural radiation in the Denver area currently is estimated as 3.5×10^{-1} rem (3.5×10^{-3} Sv).(Na87) The 50-year dose commitment of

*Sv (Sievert) = 1 J kg^{-1} = 100 rem.

6.6×10^{-4} rem represents less than 1 percent of the DOE interim radiation protection standard of 0.1 rem effective dose equivalent for all pathways. If all the dose were received from the air pathway, the bone surfaces dose of 1.1×10^{-2} rem would represent less than 15 percent of the air pathway standard for any organ.(Va85)

For community locations, the maximum radiation dose resulted in a 50-year dose commitment of 1.4×10^{-4} rem (1.4×10^{-6} Sv) effective dose equivalent and 2.7×10^{-3} rem (2.7×10^{-5} Sv) to bone surfaces. These values represent 0.1 percent of the DOE interim standard for effective dose equivalent and 4 percent of the standard for any organ from the air pathway only.(Va85) These values include contributions from residual fallout caused by past atmospheric weapons testing.

The 50-year committed effective dose equivalent to the population living within 80 kilometers (50 miles) of the plant was based on the maximum community dose estimates. For the community, the maximum effective dose equivalent was less than the 1×10^{-3} rem dose equivalent specified by DOE as *de minimis* (inconsequential).(US80b) The dose commitment for all individuals to a distance of 80 kilometers, was therefore, considered to be *de minimis*.

In demonstration of compliance with the EPA Clean Air Act air emissions standard in 40 CFR 61, Subpart H, the AIRDOS-EPA computer code was used to calculate radiation dose to the public by atmospheric dispersion, deposition, and ecological modeling of 1987 air emissions data.(Va85) The results of this calculation confirm that the maximum radiation dose to a member of the public as a result of exposure to airborne radioactivity from the Rocky Flats Plant in 1987 was less than 1 mrem effective dose equivalent.

IV. MONITORING DATA: COLLECTION, ANALYSES, AND EVALUATION

This section describes Rockwell International's environmental monitoring program for 1987, results of sample analyses, and evaluation of the data with regard to applicable guides and standards. The reader is directed to the appendixes at the end of this report for detailed information concerning applicable guides and standards, quality control, analytical procedures, detection limits, error term propagation, and reporting of minimum detectable concentrations. Appendix E includes a discussion of the methodology used for reporting measurements that were at or below the minimum detectable concentrations (MDC). This appendix also discusses the use of the less-than sign (<) and defines the use of plus or minus (±) error terms in the data.

A. Airborne Effluent Monitoring

In 1987 production and research facilities at the Rocky Flats Plant were equipped with 50 ventilation exhaust systems. Particulates generated by production and research activities are entrained in the exhaust air streams. These particulate materials are removed from the air stream in each exhaust system by means of High Efficiency Particulate Air (HEPA) filters. Residual particulates in each of these systems are continuously sampled downstream from the final stage of HEPA filters. For immediate detection of abnormal conditions, ventilation systems that service areas containing plutonium are equipped with Selective Alpha Air Monitors (SAAMs). These SAAMs are sensitive to specific alpha particle energies and are set to detect plutonium-239 and -240. These detectors are tested and calibrated routinely to maintain sensitivity. The monitors alarm automatically if out-of-tolerance conditions are experienced. No such conditions occurred during 1987.

Three times each week, continuously collected particulate samples are removed from each exhaust system and radiometrically analyzed for long-lived alpha emitters. The concentration of long-lived alpha emitters is indicative of the effluent quality and the overall performance of the HEPA filtration systems. If the total long-lived alpha concentration for an effluent sample exceeds the plant action guide value of 0.020×10^{-12} μCi/mℓ (7.4×10^{-4} Bq/m^3), a followup investigation is conducted to determine the cause and to evaluate the need for corrective action. The action guide is equal to the offsite DCG for plutonium activity in air.

TABLE 2. Radioisotopes in Airborne Effluents

Sample Period	Plutonium[a] Number of Analyses	Plutonium[a] Total Discharge (μCi)	Plutonium[a] C_{max}[c] (× 10^{-12} μCi/mℓ)	Uranium[b] Number of Analyses	Uranium[b] Total Discharge (μCi)	Uranium[b] C_{max}[c] (× 10^{-12} μCi/mℓ)	Tritium Number of Analyses	Tritium Total Discharge (Ci)	Tritium C_{max}[c] (× 10^{-12} μCi/mℓ)
January	46	1.39	0.095 ± 0.0155[d]	54	2.15	0.017 ± 0.0013[d]	262	0.005	410 ± 180[d]
February	46	0.89	0.071 ± 0.0081	56	1.99	0.095 ± 0.0091	250	0.008	250 ± 80
March	48	1.84	0.229 ± 0.0278	56	1.12	0.005 ± 0.0004	293	0.004	470 ± 180
April	45	2.02	0.016 ± 0.0013	53	0.87	0.004 ± 0.0005	246	0.007	270 ± 60
May	48	1.28	0.104 ± 0.0175	56	0.94	0.003 ± 0.0004	276	0.013	560 ± 210
June	45	0.69	0.005 ± 0.0012	53	0.98	0.003 ± 0.0004	293	0.005	260 ± 60
July	57	1.22	0.019 ± 0.0021	65	1.21	0.004 ± 0.0005	262	0.013	420 ± 160
August	45	0.65	0.010 ± 0.0011	53	1.91	0.006 ± 0.0008	249	0.025	3402 ± 570
September	45	0.63	0.003 ± 0.0003	53	1.31	0.004 ± 0.0003	275	0.031	8580 ± 900
October	45	1.80	0.006 ± 0.0007	53	1.50	0.004 ± 0.0003	291	0.003	875 ± 300
November	45	1.42	0.015 ± 0.0015	53	1.13	0.002 ± 0.0004	253	0.051	8748 ± 850
December	45	1.53	0.016 ± 0.0018	53	1.66	0.008 ± 0.0013	253	0.005	729 ± 200
Summary	560	15.36	0.229 ± 0.0278	658	16.77	0.095 ± 0.0091	3203	0.170	8748 ± 850

a. Radiochemically determined as plutonium-239, -240.
b. Radiochemically determined as uranium-233, -234, and -238.
c. C_{max} is the maximum measured concentration.
d. Calculated as 1.96 standard deviations on an individual measurement.

At the end of each month, samples from each exhaust system are composited into individual samples to undergo specific chemical analysis. An aliquot of each of the dissolved composite-samples is analyzed for beryllium particulates using flameless atomic absorption spectrometry techniques. (Bo68) The remainder of the dissolved sample is subjected to chemical separation and alpha spectral analysis that quantifies specific alpha-emitting radionuclides. Analyses for uranium isotopes are conducted on the composite samples from each exhaust system. In 1987, forty-two of the ventilation exhaust systems were located in buildings that contain plutonium. Particulate samples from these exhaust systems were also analyzed for specific isotopes of plutonium.

Continuous sampling for tritium is conducted in 23 ventilation exhaust systems. Bubbler-type samplers are used to collect samples three times each week from these locations. Tritium concentrations in the samples are measured using a liquid scintillation photospectrometer.

Table 2 presents the quantitative data for radioisotopes in airborne effluents during 1987. Tritium values include contributions from background radioactivity.

During 1987 the total quantity of plutonium discharged to the atmosphere from the plutonium exhaust systems was 15.36 μCi (5.68 × 10^5 Bq).

The maximum plutonium concentration of 0.229 × 10^{-12} μCi/mℓ (8.47 × 10^{-3} Bq/m^3) was measured from a waste treatment facility during a 2-day period in March. The quantity of plutonium in this discharge was 0.043 μCi (1.59 × 10^3 Bq). Samples collected prior to, and following this two-day period were within the range typically measured from this exhaust system.

The total discharge of uranium from all the exhaust systems was 16.77 μCi (6.20 × 10^5 Bq). The maximum uranium concentration of 0.095 × 10^{-12} μCi/mℓ (3.52 × 10^{-3} Bq/m^3) was measured from a depleted uranium production facility during a 2-day period in February. The quanity of depleted uranium from this discharge was 0.221 μCi (8.18 × 10^3 Bq). The tritium discharged from 23 ventilation systems was 0.17 Ci (6.3 × 10^9 Bq). The maximum tritium concentration of 8748 × 10^{-12} μCi/mℓ (3.24 × 10^2 Bq/m^3) was observed in a sample from a routine operation in a plutonium production building during November. The quantity of tritium released to the atmosphere as the result of this operation was 0.009 μCi (3.33 × 10^2 Bq).

TABLE 3. Beryllium in Airborne Effluents

Sample Period	Number of Analyses	Total Discharge[a] (g)	C_{max} ($\mu g/m^3$)
January	54	0.0276	0.00042
February	56	0.0085	0.00006
March	56	0.0091	0.00014
April	53	0.0130	0.00010
May	56	0.0143	0.00011
June	53	0.0137	0.00014
July	65	0.0099	0.00008
August	53	0.0207	0.00021
September	53	0.0048	0.00004
October	53	0.0233	0.00012
November	53	0.0045	0.00005
December	53	0.0154	0.00007
Summary	658	0.1648[b]	0.00042

a. The beryllium stationary-source emission-standard is no more than 10 grams of beryllium over a 24-hour period under the provisions of subpart C of 40 CFR 61.32(a). (US78)

b. This value is not significantly different from the background associated with the analyses.

Overall, the radionuclide releases to the atmosphere during 1987 were in the normal ranges projected in the Plant Environmental Impact Statement, and represent no adverse environmental impact.

Table 3 presents the beryllium airborne effluent data for 1987. The total quantity of beryllium discharged from the ventilation exhaust systems was not significantly above the background levels associated with the analyses.

B. Radioactive Ambient Air Monitoring

High-volume ambient air samplers are located on the Rocky Flats plantsite, at the plant perimeter [at distances of approximately 3 to 6 kilometers (2 to 4 miles) from the plant's center], and in surrounding communities. These Rocky Flats-designed air samplers operate continuously at a volume flow rate of approximately 12 ℓ/sec (25 ft^3/min), collecting air particulates on 20- X 25-cm (8- X 10-in.) fiberglass media. Manufacturer's test specifications rate this filter media to be 99.97% efficient for the relevant particle sizes under conditions typically encountered in routine ambient air sampling.(Sc82)

Airborne particulates in ambient air are sampled continuously at 23 locations within and adjacent to the Rocky Flats exclusion area (Figure 7). The sample filters are collected biweekly and analyzed for total long-lived alpha (TLLα) radiation. If the TLLα concentration for an ambient air sample exceeds the plant guide value [10×10^{-15} μCi/mℓ (3.7×10^{-4} Bq/m^3)], a specific plutonium analysis is performed. During 1987, three samples exceeded the TLLα screening level and were analyzed for plutonium. The results of these analyses have been included in Table 4.

Filters from 5 of the 23 onsite samplers are routinely analyzed biweekly for plutonium. These five onsite samplers have historically shown the highest plutonium concentrations for the sampling network. Table 4 contains the mean concentrations of plutonium in ambient air at these stations during 1987, as well as the minimum and maximum concentrations measured throughout the year.

The mean concentrations of plutonium in ambient air at the five onsite stations during 1987 ranged from 0.117×10^{-15} to 1.222×10^{-15} μCi/mℓ (4.33×10^{-6} to 4.52×10^{-5} Bq/m^3). These concentrations are less than 7 percent of the offsite Derived Concentration Guide (DCG) for plutonium in air.

Monitoring for tritium in ambient air is conducted at onsite locations S-4, S-5, and S-16 (Figure 7). Samples are collected and analyzed weekly. The tritium samplers operate continuously at a sampling rate of one-to-two liters of air per minute. Water vapor in the sampled air is collected in a Pyrex tube filled with silica gel. The sampling equipment is contained in an aluminum case that is insulated, weathertight, and lockable. Temperature inside the case is controlled by a small heater and a fan that maintain a temperature between 4.44 and 32.2 °C (40 and 90 °F). Table 5 presents the mean concentrations of tritium in ambient air at these three onsite stations during 1987.

Annual mean concentration of tritium in ambient air at the three onsite stations during 1987 ranged from 0.07×10^{-12} to 0.26×10^{-12} μCi/mℓ air (2.6×10^{-3} to 9.6×10^{-3} Bq/m^3). These concentrations are less than 0.0002 percent of the offsite DCG for tritium in air.

TABLE 4. Plutonium-239 and -240 Activity Concentrations in Onsite Ambient Air at Selected Locations[a]

Station	Number of Analyses	Volume[d] (× 1000 m^3)	Concentration[b] (× 10^{-15} μCi/mℓ)[c] C_{min}	C_{max}	C_{mean}	Standard Deviation (C_{mean})	Percent[c] of DCG (C_{mean})
S-5	26	287	0.034	0.729	0.117	0.194	0.58
S-6	25	345	0.010	1.815	0.203	0.509	1.01
S-7	25	347	0.075	4.170	0.770	1.114	3.85
S-8	26	379	0.148	3.018	0.885	0.789	4.42
S-9	26	407	0.302	3.878	1.222	1.012	6.11
S-4	1	7	0.002	0.002	0.002		0.01
S-11	1	7	-0.001	-0.001	-0.001		-0.01
S-18	2	34	0.007	0.007	0.007		0.04

a. Air-sampling stations S-5, S-6, S-7, S-8, and S-9 are located in areas where the potential for elevated airborne radioactivity is greatest (see Figure 7). Samples from stations S-4 (taken 12/15/87 to 12/21/87), S-11 (taken 1/6/87 to 1/13/87), and S-18 (taken 12/23/86 to 1/27/87) exceeded the screening guide of 10 × 10^{-15} μCi/mℓ total long-lived alpha activity. Specific plutonium analyses were performed on these samples. The results of these analyses are included for completeness.

b. Concentrations reflect monthly composites of station concentrations. C_{min} = Minimum composited concentration; C_{max} = Maximum composited concentration; C_{mean} = Mean composited concentration.

c. To obtain the proper concentration, multiply the numbers listed in the table by 1 × 10^{-15} μCi/mℓ. For example, the mean concentration at S-5 was 0.117 × 10^{-15} μCi/mℓ.

d. To obtain the proper volume, multiply the numbers listed in the table by 1000 m^3. For example, volume sampled at S-5 was 287,000 m^3.

e. The interim standard calculated Derived Concentration Guide (DCG) for inhalation of class W plutonium by members of the public is 20 × 10^{-15} μCi/mℓ. (See Appendix A.)

TABLE 5. Tritium Activity Concentrations in Onsite Ambient Air

Station	Number of Analyses	Air Volume (m^3)	Condensed Water Vapor (mℓ)	Concentration[a] (× 10^{-12} μCi/mℓ air)[b] C_{min}	C_{max}	C_{mean}	Standard Deviation (C_{mean})	Percent[c] of DCG (C_{mean})
S-4	48	624	1397	-0.31 ± 1.08	1.03 ± 1.57	0.23	0.42	0.00011
S-5	41	420	1032	-1.04 ± 1.08	1.88 ± 1.06	0.07	0.84	0.00003
S-16	47	689	1475	-0.82 ± 0.91	1.38 ± 1.02	0.26	0.60	0.00013

a. Concentrations reflect monthly composites of station concentrations. C_{min} = Minimum composited concentration; C_{max} = Maximum composited concentration; C_{mean} = Mean composited concentration.

b. To obtain the proper concentration, multiply the number of the table by 1 × 10^{-12} μCi/mℓ. For example, the mean concentration at S-4 was 0.23 × 10^{-12} μCi/mℓ.

c. The interim standard calculated offsite Derived Concentration Guide (DCG) for tritium in air is 200,000 × 10^{-12} μCi/mℓ. (See Appendix A.)

Samples of airborne particulates are collected on filters by high-volume air samplers at 14 locations along or near the plant perimeter. These perimeter samplers are located between 3 and 6 kilometers (2 and 4 miles) from the plant center. (Figure 7.) The samplers are numbered S-31 through S-44. Samples from each location are collected biweekly, composited by location, and analyzed for a four-week period for plutonium. Table 6 presents the average concentrations of plutonium radioactivity in airborne particulates at Stations S-31 through S-44 during 1987. The mean concentration of plutonium in ambient air at these locations during 1987 was 0.005 × 10^{-15} μCi/mℓ (1.85 × 10^{-7} Bq/m^3). This concentration is 0.03 percent of the offsite DCG for plutonium in air.

One perimeter sampler measured higher than normal plutonium concentrations for one month during 1987. The maximum point estimate recorded at sampler S-34 was 0.263 × 10^{-15} μCi/mℓ (9.74 × 10^{-6} Bq/m^3), measured in August. Investigation revealed no conclusive explanation for this value. There were no indications that it

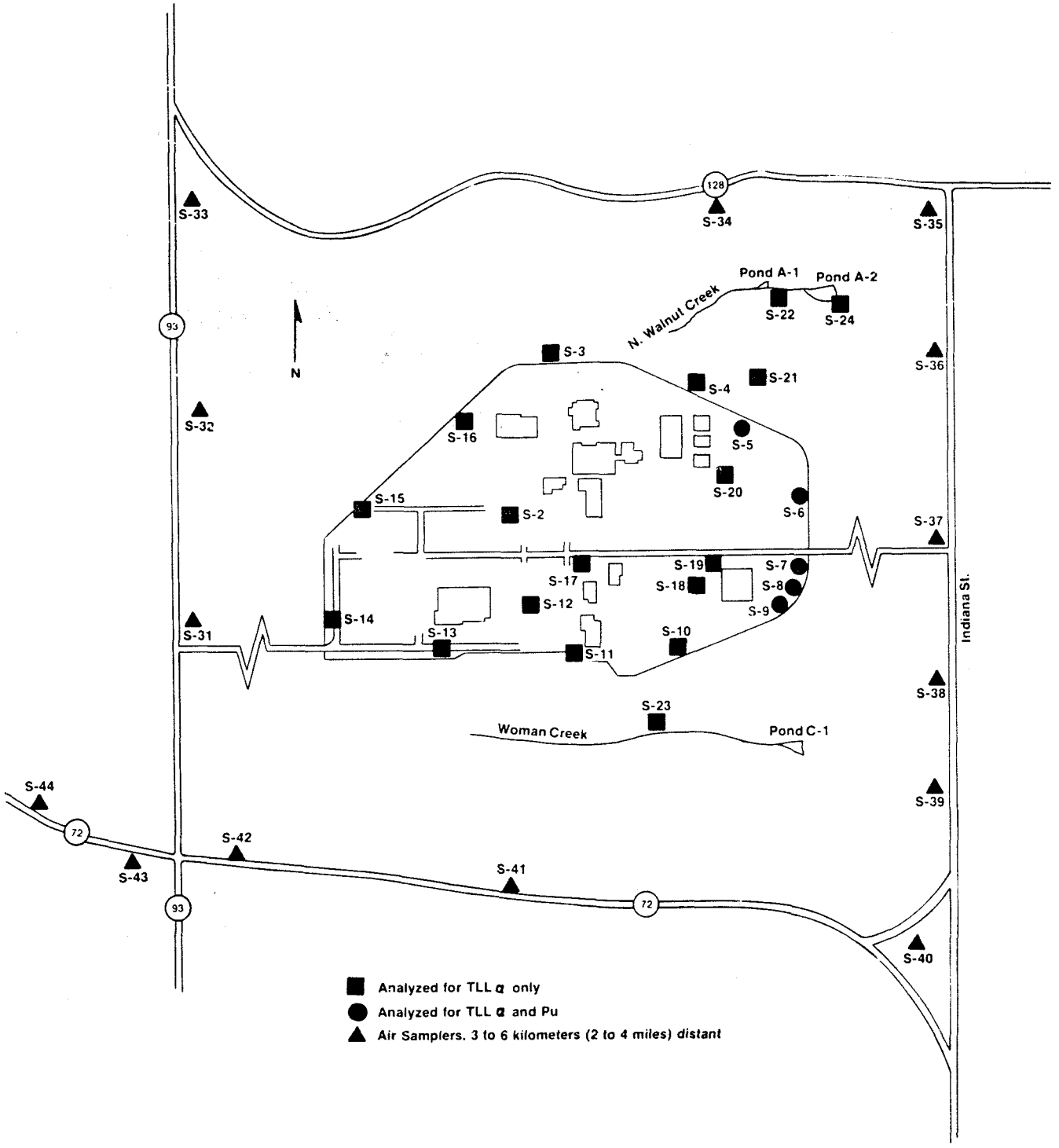


FIGURE 7. Location of Onsite and Plant Perimeter Ambient Air Samplers
(Portions of figure are not to scale.)

TABLE 6. Plutonium-239 and -240 Activity Concentrations in Perimeter Ambient Air

Station	Number of Analyses	Volume[b] ($\times$ 1000 m^3)	Concentration ($\times 10^{-15}$ μCi/mℓ)[a] C_{min}	C_{max}	C_{mean}	Standard Deviation (C_{mean})	Percent[c] of DCG (C_{mean})
S-31	11	294	0.000	0.013	0.003	0.004	0.02
S-32	12	313	-0.001	0.014	0.002	0.004	0.01
S-33	12	365	-0.001	0.004	0.001	0.002	0.01
S-34	12	321	-0.001	0.263	0.024	0.075	0.12
S-35	12	293	-0.001	0.018	0.003	0.006	0.02
S-36	12	355	0.001	0.022	0.007	0.006	0.04
S-37	12	351	0.002	0.011	0.007	0.003	0.04
S-38	12	362	0.000	0.018	0.005	0.005	0.02
S-39	12	388	-0.001	0.006	0.002	0.002	0.01
S-40	12	338	-0.001	0.010	0.003	0.003	0.02
S-41	12	321	0.000	0.009	0.003	0.003	0.02
S-42	12	355	-0.001	0.004	0.001	0.002	0.01
S-43	12	390	-0.001	0.006	0.002	0.002	0.01
S-44	12	355	-0.001	0.010	0.002	0.003	0.01
Summary	167		-0.001	0.263	–	–	–
Average	–	–	–	–	0.005	0.00857	0.03

a. To obtain the proper concentration, multiply the numbers listed in the table by 1 $\times$ 10^{-15} μCi/mℓ. For example, the mean concentration at S-31 was 0.003 $\times$ 10^{-15} μCi/mℓ.

b. To obtain the proper volume, multiply the number listed in the table by 1000 m^3. For example, the volume sampled at S-31 was 294,000 m^3.

c. The interim standard claculated Derived Concentration Guide (DCG) for inhalation of Class W plutonium by members of the public is 20 $\times$ 10^{-15} μCi/mℓ.

was related to any activities at the plant. It has been included in Table 6. This value is less than 1.4 percent of the offsite DCG for plutonium in air.

Samples of airborne particulates are also collected at 14 locations in or near communities in the vicinity of the Rocky Flats Plant. These locations, shown in Figure 8, are Boulder, Broomfield, Cotton Creek, Denver, Golden, Jeffco Airport, Lafayette, Lakeview Pointe, Leyden, Marshall, Superior, Wagner, Walnut Creek, and Westminster. Sample filters are collected biweekly, composited by location for a four-week period, and analyzed for plutonium radioactivity. Table 7 presents the average concentrations of plutonium in airborne particulates at the community stations during 1987. The mean concentration of plutonium in ambient air at the community stations was 0.003 $\times$ 10^{-15} μCi/mℓ (1.11 $\times$ 10^{-7} Bq/m^3). This value is 0.02 percent of the offsite DCG for plutonium in air.

The Westminster community air sampler recorded one abnormal value in 1987. The November point estimate of the plutonium concentration in the ambient air at the Westminster sampler was 0.299 $\times$ 10^{-15} μCi/mℓ (1.1 $\times$ 10^{-5} Bq/m^3). Investigation revealed no conclusive explanation for this value. There were no indications that it was related to any Rocky Flats Plant activities. The value has been included in Table 7. This value is less than 1.5 percent of the offsite DCG for plutonium in air.

C. Nonradioactive Ambient Air Monitoring

During 1987, monitoring of ambient air included the following parameters: total suspended particulates (TSP), ozone, sulfur dioxide, carbon monoxide, nitrogen dioxide, and lead. This monitoring utilized instrumentation in a self-contained shelter equipped for field sampling of ambient air. These six parameters are criteria pollutants regulated by the EPA and the State of Colorado through the Clean Air Act Amendments of 1970 and 1977, which include the National Ambient Air Quality Standards (NAAQS) and

FIGURE 8. Location of Community Ambient Air Samplers

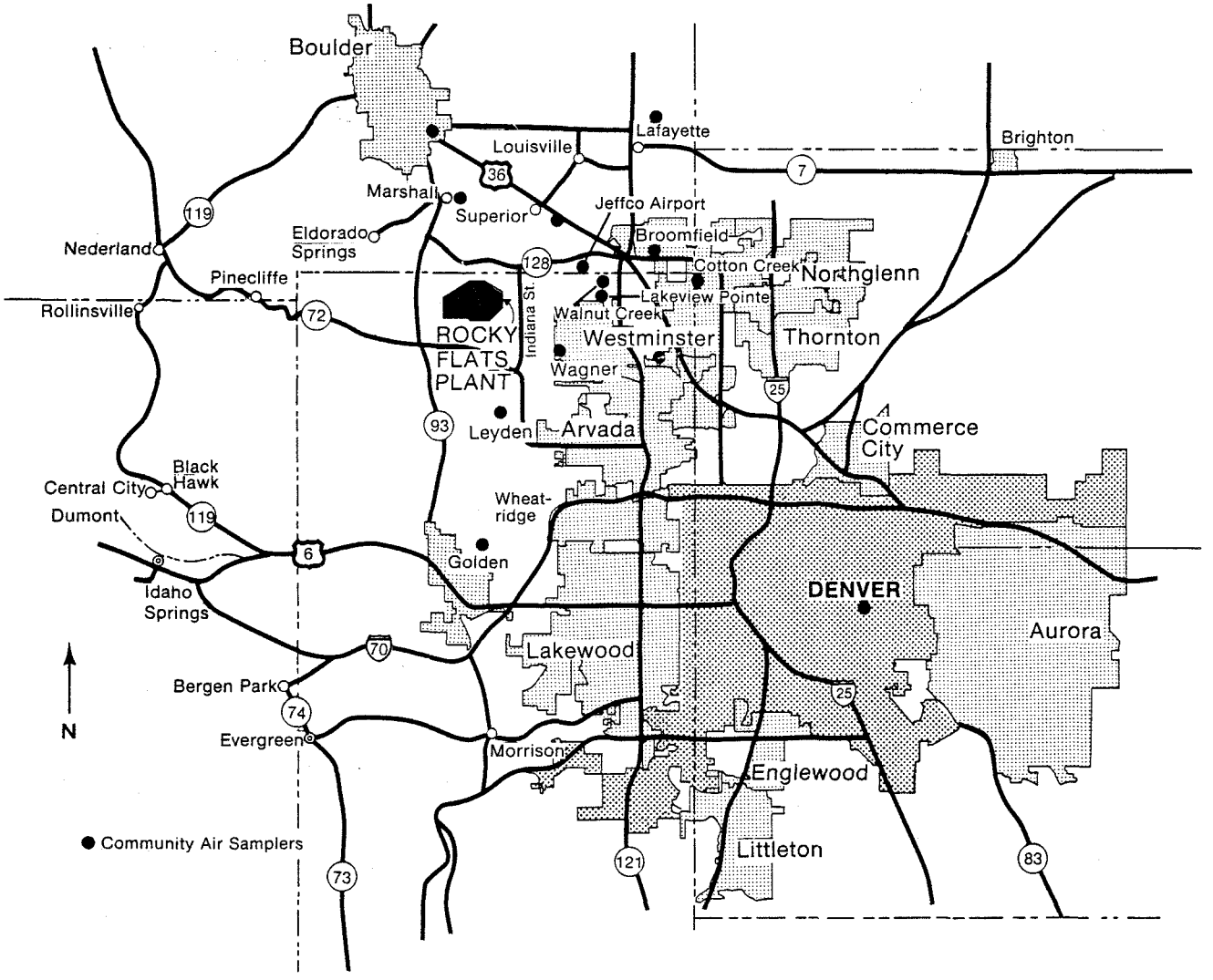


TABLE 7. Plutonium-239 and -240 Concentrations in Community Ambient Air

Station	Number of Analyses	Volume[b] (× 1000 m³)	Concentration (× 10^{-15} μCi/mℓ)[a]			Standard Deviation (C_{mean})	Percent[c] of DCG (C_{mean})
			C_{min}	C_{max}	C_{mean}		
Marshall	12	315	-0.001	0.005	0.002	0.002	0.01
Jeffco Airport	12	342	0.000	0.010	0.003	0.003	0.02
Superior	12	327	-0.001	0.004	0.001	0.002	0.01
Boulder	12	364	0.000	0.004	0.001	0.001	0.01
Lafayette	12	344	0.000	0.004	0.002	0.001	0.01
Broomfield	12	301	-0.001	0.008	0.002	0.003	0.01
Walnut Creek	12	384	-0.001	0.005	0.002	0.002	0.01
Wagner	12	367	0.000	0.007	0.003	0.003	0.02
Leyden	12	337	-0.001	0.008	0.001	0.002	0.01
Westminster	12	279	-0.002	0.299	0.026	0.086	0.13
Denver	12	319	-0.006	0.005	0.001	0.003	0.01
Golden	12	363	-0.001	0.007	0.001	0.003	0.01
Lakeview Pointe	12	365	0.000	0.008	0.002	0.002	0.01
Cotton Creek	12	345	-0.001	0.005	0.001	0.002	0.01
Summary	168		-0.006	0.299	–	–	–
Average	–	–	–	–	0.003	0.00821	0.02

a. To obtain the proper concentration, multiply the numbers listed in the table by 1 × 10^{-15} μCi/mℓ. For example, the mean concentration at Marshall was 0.002 × 10^{-15} μCi/mℓ.
b. To obtain the proper volume, multiply the numbers listed in the table by 1000 m³. For example, the volume sampled at Marshall was 315,000 m³.
c. The interim standard calculated offsite Derived Concentration Guide (DCG) for inhalation of Class W plutonium by members of the public is 20 × 10^{-15} μCi/mℓ.

Colorado Air Quality Control Commission Ambient Air Standards. Table 8 identifies the detection methods and operating ranges of the monitoring analyzers with corresponding compliance standards. During 1987, the monitoring shelter remained stationary at a location near the east entrance to the plant. This is an open area near a traffic zone and is generally downwind from plant buildings. Ambient air data were collected over the entire year with some limited loss of data due to problems with the data acquisition system.

Final promulgation of EPA's respirable particulates (PM-10) standards was issued July 1, 1987.(US87a) Reference methods for this new PM-10 standard were issued by EPA on October 6, and December 1, 1987.(US87b) The PM-10 sampler that the Rocky Flats Plant has purchased is one of the two accepted sampler designs specifically described in the October 6, 1987, Federal Register discussion. (US84b) These units will be put into routine service for the 1988 sampling period. The reference method for ambient lead sampling is still the HiVolume sampler. The use of both TSP and PM-10 sampling is encouraged by CDH until specific changes are made in state regulations that reflect the PM-10 changes in the federal regulations. Therefore, total suspended particulates (TSP) sampling using HiVolume samplers will continue indefinitely.

Measurements of TSP and lead were conducted using the EPA reference high-volume air sampling method. The primary ambient air particulate sampler and a co-located duplicate sampler were operated on the EPA's sampling schedule of once every sixth day. Particulate data are shown in Table 9. The highest TSP value recorded (a 24-hour sample) was 100 μg/m³, which is 38 percent of the 24-hour primary standard of 260 μg/m³. The annual geometric mean value for 1987 was 41 μg/m³, which was 55 percent of the NAAQS primary annual geometric mean standard of 75 μg/m³.

The quarterly average lead concentrations in air (taken from HiVol samples) for 1987 were well below the primary quarterly standard of 1.5 μg/m³. The highest quarterly value detected was

TABLE 8. Ambient Air Monitoring Detection Methods and National Ambient Air Quality Standards (NAAQS) for Total Suspended Particulates, Ozone, Sulfur Dioxide, Carbon Monoxide, Nitrogen Dioxide, and Lead

Parameter	Detection Methods and Analyzer Ranges	NAAQS Averaging Time	Concentration
Total Suspended Particulates (TSP)	Reference Method (Hi Volume) 24-Hour sampling (6th-day scheduling)	Annual Geometric Mean: Primary[a] Secondary[b]	 75 $\mu g/m^3$ 60 $\mu g/m^3$
		24-Hour Primary[a,c] Secondary[b,c]	 260 $\mu g/m^3$ 150 $\mu g/m^3$
Ozone (O_3)	ThermoElectron Model 49 Ultraviolet Photometry 0–0.5 ppm	1-Hour Primary[a,d]	 0.12 ppm
Sulfur Dioxide (SO_2)	ThermoElectron Model 43 Pulsed Fluorescence 0-0.5 ppm	Annual Arithmetic Mean: Primary[a]	 0.030 ppm
		24-Hour Secondary 3-Hour	0.140 ppm 0.500 ppm
Carbon Monoxide (CO)	ThermoElectron Model 48 Gas Filter Correlation (infrared) 0–50 ppm	1-Hour Primary[a,c]	 35 ppm
		8-Hour Primary[a,c]	 9 ppm
Nitrogen Dioxide (NO_2)	Monitor Labs Model 8840 Chemiluminescent 0–0.5 ppm	Annual Arithmetic Mean: Primary[a]	 0.05 ppm
Lead	Reference Method (Hi Volume) 24-Hour Sampling (Atomic Absorption Analysis)	Calendar Quarter Primary[a]	 1.5 $\mu g/m^3$

a. Primary NAAQS are intended to protect public health.
b. Secondary NAAQS are intended to protect public welfare.
c. Not to be exceeded more than once per year.
d. Statistically estimated number of days with concentrations in excess of the standard is not to be more than 1.0 per year.

0.033 $\mu g/m^3$ collected during April, May, and June, which is less than three percent of the EPA standard.

Ambient ozone data were collected using an ultraviolet (U.V.) photometric type analyzer. During 1987, a total of 8,143 1-hour ozone samples were collected. The maximum 1-hour value was 0.135 ppm, which is 112 percent of the primary one-hour standard of 0.120 ppm. The second highest 1-hour ozone value, which occurred during the same afternoon in August was 0.134 ppm. These values are consistent with levels measured in the general Denver metropolitan area during high pollution episodes.

Sulfur dioxide sampling was conducted using a continuously operating pulsed fluorescence type analyzer calibrated by use of a certified cylinder gas and a dynamic gas dilution calibration system. The cylinder gases, as well as the mass flowmeters, have traceability to primary standards set by the National Bureau of Standards. The maximum 1-hour SO_2 value recorded at the plant was 0.025 ppm and the maximum observed 3-hour average value was 0.021 ppm, which is 4 percent of the EPA 3-hour standard of 0.500 ppm. The calculated annual arithmetic mean value of 0.003 ppm is 10 percent of the NAAQS annual arithmetic mean standard of 0.030 ppm. The maximum observed 24-hour average for SO_2 was 0.010 ppm, which

TABLE 9. Onsite Ambient Air Quality Data

(Nonradioactive Parameters)
1987

Total Suspended Particulates ($\mu g/m^3$)	
Total Number of Samples - "A"[a]	60
Total Number of Samples - "B"[b]	58
Geometric Mean, Sampler "A"	40.9
Geometric Mean, Sampler "B"	39.2
Standard Deviation, Sampler "A"	21.8
Standard Deviation, Sampler "B"	21.5
Observed 24-Hour Maximum, "A"	100.1
Observed 24-Hour Maximum, "B"	97.2
Second Highest Maximum, "A"	97.5
Second Highest Maximum, "B"	96.5
Lowest Observed Value, "A"	8.8
Lowest Observed Value, "B"	5.2
Ozone (ppm)	
Number of Observations, Hourly[c]	8,143
Arithmetic Mean, Annual	0.036
Maximum 1-Hour Concentration	0.135
Second Highest 1-Hour Concentration	0.134
Minimum Observation, Hourly	0.003
Carbon Monoxide (ppm)	
Number of Observations, Hourly[c]	8,400
Arithmetic Mean, Annual	0.69
Maximum 1-Hour Concentration	6.50
Second Highest 1-Hour Concentration	4.90
Maximum 8-Hour Concentration	2.30
Minimum Hourly Observation	0.05
Nitrogen Dioxide (ppm)	
Number of Observations, Hourly[c]	7,500
Arithmetic Mean	0.005
Maximum 1-Hour Concentration	0.064
Minimum Hourly Observation	0.001
Sulfur Dixoide (ppm)	
Number of Observations, Hourly[c]	8,284
Arithmetic Mean, Annual	0.003
3-Hour Average, Highest	0.021
24-Hour Average, Highest	0.010
Maximum 1-Hour Concentration	0.025

Air borne Lead ($\mu g/m^3$)

	Jan-Mar	Apr-June	Jul-Sep	Oct-Dec
Total Number of Samples	6	7	6	6
Quarterly Avg.	0.015	0.033	0.018	0.010

a. Primary ambient air particluate sampler.
b. Co-Located duplicate sampler.
c. Continuous millivolt analyzer output is composited and converted to engineering units for comparison to NAAQS (see Table 8).

is 7 percent of the NAAQS 24-hour standard of 0.140 ppm.

The 8,400 hourly averages of carbon monoxide (CO) data collected during 1987, using a gas filter correlation infrared type analyzer, yielded an annual arithmetic mean of 0.69 ppm, including a maximum 1-hour average value of 6.50 ppm, which is 19 percent of the primary 1-hour standard of 35 ppm. A maximum 8-hour average concentration value of 2.30 ppm was recorded, which is 25 percent of the 8-hour primary standard of 9 ppm.

The nitrogen dioxide (NO_2) data contain 7,500 hourly averages of continuous sampling and gave an annual arithmetic mean of 0.005 ppm, which is 10 percent of the NAAQS primary annual arithmetic mean standard value of 0.05 ppm. The maximum 1-hour value noted during this time period was 0.064 ppm.

The data for all parameters were assessed with an accuracy of ± 15 percent based on routine precision and operational span checks, multipoint dynamic calibrations, and established quality assurance procedures.

As part of an ongoing quality assurance program, all of the analyzers were again subjected to an independent annual audit during 1987. Responses of all analyzers were within the range of established EPA guidelines for an ambient air monitoring network (± 15%).

D. Waterborne Effluent Monitoring

North Walnut Creek receives surface water runoff from the north side of the plantsite. (See Figure 4.) Holding Pond A-3 on North Walnut Creek is used to impound this surface runoff for analysis prior to discharge. A second control point, holding Pond A-4, is located further downstream.

Ponds A-1 and A-2 are isolated by valves from North Walnut Creek. In the past, these ponds have been used for storage and evaporation of laundry water. This practice was discontinued in 1980. These ponds currently are maintained in a state of readiness for control of possible chemical spills

into the North Walnut Creek drainage basin. Disposition of Pond A-1 and A-2 runoff water is through natural evaporation and is enhanced by spraying water through fog nozzles over the surface of the ponds. Excess water that does not evaporate is then recollected by the ponds.

South Walnut Creek receives surface water runoff from the central portion of the plant. This water is diverted through a culvert system to Pond B-4 and then to Pond B-5 where the water is impounded for analysis prior to controlled offsite discharge.

In the past, treated sanitary wastewater was also routinely discharged to South Walnut Creek. This practice was discontinued in 1979. Currently, discharges occur only when weather conditions do not permit onsite spray irrigation. Between 1981 and 1987, some treated sanitary wastewater has been recycled through the plant Reverse Osmosis (RO) Facility for further treatment and reused in plant cooling towers. Excess water that could not be recycled was discharged directly to Pond B-3 or pumped into the RO holding ponds and spray-irrigated onto Rocky Flats buffer zone areas. Ponds B-1 and B-2, also located in the central drainage, are reserved as backup control ponds. These ponds can be used to retain chemical spills, surface water runoff, or treated sanitary wastewater.

Surface runoff water from the south side of the plant is collected in an interceptor ditch and flows to surface water control Pond C-2, where the water is impounded and analyzed before discharge offsite. Woman Creek, also in the south drainage, is isolated from this diversion system. Pond C-1 is used as the monitoring point for Woman Creek.

Discharges from the Rocky Flats Plant are monitored for compliance with appropriate Colorado Department of Health Standards and EPA National Pollutant Discharge Elimination System (NPDES) permit limitations.(US84a) Annual average concentrations of chemical and biological constituents of liquid effluent samples collected from Ponds A-3, A-4, B-3, B-5, and C-2 during 1987 are presented in Table 10. The data are indicative of overall water quality for these ponds.

During 1984, the plant NPDES permit expired and was replaced by a renewed NPDES permit with the same seven discharge locations 001, 002, 003, 004, 005, 006, and 007. The discharge locations are indentified in Table 10. The NPDES permit places monitoring and reporting requirements and limitations on daily concentrations and monthly average concentrations for specific parameters. There were two violations of the NPDES permit during 1987. One of the violations consisted of an unauthorized discharge to Woman Creek of spray irrigated water from Pond B-3 on March 2, 1987. The other violation was issued for exceeding the allowable Biochemical Oxygen Demand (BOD_5) during the month of May 1987.

Spray irrigation of treated sanitary wastewater has been done in accordance with good engineering practices since 1979 at the Rocky Flats Plant. On March 2, 1987, some surface runoff of the sprayed treated sanitary effluent occurred due to the saturation of the spray field area with snow melt. The combined snow melt and treated sanitary wastewater flowed by natural drainage into the Woman Creek drainage. This water circumvented the permitted NPDES discharge locations resulting in a technical violation of the Rocky Flats NPDES permit.

Corrective actions taken to preclude a reoccurrence of the surface runoff include: (1) discharge of the treated sanitary wastewater through Discharge 001 when weather conditions prevent proper spray irrigation; (2) installation of a perimeter trench around the primary spray field to divert surface flows into discharge location 007; and (3) enhanced administrative controls by Rockwell personnel to provide additional surveillance of the spray irrigation fields. Analytical results from samples of the treated sanitary wastewater effluent at the advanced waste water treatment plant showed good water quality and no adverse impact was detected on Woman Creek.

The BOD_5 violation occurred in May 1987 after three separate discharges occurred during the month. The average of the three BOD analyses was 15 mg/ℓ. This is above the allowable monthly average limit of 10 mg/ℓ and a technical violation of the NPDES permit occurred. There were no

TABLE 10. Annual Average Concentrations of Chemical and Biological Constituents in Liquid Effluents[a]

Parameter	Number of Analyses	C_{min}	C_{max}	C_{mean}
Discharge 001[b]				
pH,SU[c]	33	6.6	7.5	–
Nitrate as N, mg/ℓ	33	<0.4	3.2	1.4
Total Suspended Solids, mg/ℓ	33		19.0	8.5
Total Residual Chlorine, mg/ℓ	33	<0.05	0.2	0.1
Total Chromium, mg/ℓ	12	<0.05	0.1	0.05
Total Phosphorus, mg/ℓ	33	0.6	6.0	1.2
Fecal Coliform, #/100 mℓ	30	<1	3.5	1.2
Biochemical Oxygen Demand (BOD_5), mg/ℓ	15		20.0	9.0
Discharge 002[b]				
pH, SU	38	7.0	8.0	–
Nitrate as N, mg/ℓ	38	–	4.2	2.4
Discharge 003[b]	During 1987, there were no discharges made to offsite waters from the Reverse Osmosis Pilot Plant.			
Discharge 004[b]	During 1987, ther were no discharges made to offsite waters from the Reverse Osmosis Plant.			
Discharge 005[b]				
pH, SU	21	7.4	8.4	–
Nitrates as N, mg/ℓ	21	0.2	5.1	1.5
Nonvolatile Suspended Solids, mg/ℓ	21	0.0	21	3.7
Discharge 006[b]				
pH, SU	36	7.0	8.7	–
Nitrates as N, mg/ℓ	36	0.2	3.8	1.4
Nonvolatile Suspended Solids, mg/ℓ	36	0.0	18.0	3.6
Discharge 007[b]				
pH, SU	15	6.9	8.1	–
Nitrates as N, mg/ℓ	15	0.2	1.3	0.5
Nonvolatile Suspended Solids, mg/ℓ	15	0.0	7.0	3.1

a. Examples of NPDES Permit limitations are presented in Table A-1.
b. The Environmental Protection Agency NPDES discharge permit defines the discharge locations as follows:
   001 - Pond B-3
   002 - Pond A-3
   003 - Reverse Osmosis Pilot Plant
   004 - Reverse Osmosis Plant
   005 - Pond A-4
   006 - Pond B-5
   007 - Pond C-2
c. SU - Standard Units

upset conditions of the sewage treatment plant observed by plant operators during the month. The cause of the elevated BOD is believed to be algal growth in Pond B-3, the treated sanitary wastewater holding pond. The Colorado regulations for effluent limitations permit a monthly average of 30 mg/ℓ for BOD_5 which is three times the limit placed on the Rocky Flats NPDES permit. Therefore, no adverse environmental impacts were anticipated from the discharge of Pond B-3.

TABLE 11. Plutonium, Uranium, and Americium Concentrations in Water at the Rocky Flats Plant

Location	Number of Analyses	C_{min}	C_{max}	C_{mean}	Percent of DCG
		Plutonium Concentration ($\times 10^{-9}$ μCi/mℓ)[a]			
Pond A-4	8	0.00 ± 0.02[b]	0.04 ± 0.03[b]	0.01 ± 0.009[c]	0.003
Pond B-5	10	−0.007 ± 0.03	0.04 ± 0.03	0.02 ± 0.007	0.007
Pond C-1	48	0.00 ± 0.007	0.08 ± 0.01	0.02 ± 0.003	0.007
Pond C-2	5	−0.02 ± 0.03	0.05 ± 0.03	0.03 ± 0.02	0.01
Walnut Creek at Indiana Street	32	−0.02 ± 0.05	7.1 ± 0.08	0.02 ± 0.004	0.007
		Uranium Concentration ($\times 10^{-9}$ μCi/mℓ)[d]			
Pond A-4	8	5.2 ± 0.5[b]	25.0 ± 3.0[b]	11.3 ± 1.2[c]	2.3
Pond B-5	12	2.7 ± 0.3	6.5 ± 0.7	4.6 ± 0.5	0.9
Pond C-1	48	0.03 ± 0.1	4.3 ± 0.5	1.3 ± 0.3	0.3
Pond C-2	5	3.6 ± 0.6	6.9 ± 0.6	5.4 ± 0.2	1.1
Walnut Creek at Indiana Street	32	0.9 ± 0.1	13.0 ± 2.0	3.8 ± 0.1	0.8
		Americium Concentration ($\times 10^{-9}$ μCi/mℓ)[e]			
Pond A-4	8	0.01 ± 0.02[b]	0.03 ± 0.02[b]	0.02 ± 0.02[c]	0.03
Pond B-5	12	−0.01 ± 0.02	0.04 ± 0.02	0.01 ± 0.008	0.02
Pond C-1	48	−0.002 ± 0.005	0.05 ± 0.02	0.01 ± 0.002	0.02
Pond C-2	5	−0.03 ± 0.05	0.03 ± 0.02	0.01 ± 0.03	0.02
Walnut Creek at Indiana Street	32	−0.02 ± 0.05	2.1 ± 0.3	0.01 ± 0.01	0.02

a. Radiochemically determined as plutonium-239 and -240. The interim standard calculated Derived Concentration Guide (DCG) for plutonium in water available to members of the public is 300 × 10^{-9} μCi/mℓ. (See Appendix A.)
b. Calculated as 1.96 standard deviations of the individual measurement.
c. Calculated as 1.96 standard deviations of the mean.
d. Radiochemically determined as uranium-233, -234, and -238. The interim standard calculated Derived Concentration Guide (DCG) for uranium in water available to members of the public is 500 × 10^{-9} μCi/mℓ. (See Appendix A.)
e. Radiochemically determined as americium-241. The interim standard calculated Derived Concentration Guide (DCG) for americium in water available to members of the public is 60 × 10^{-9} μCi/mℓ. (See Appendix A.)

Prior to discharge from Ponds A-4, B-5, and C-2, water is sampled and analyzed for gross alpha, gross beta, tritium, gamma activity, pH, nitrate as nitrogen (N), and nonvolatile suspended solids. Water is not released if the plant action level for any parameter is exceeded. In general, these action levels are based on EPA and CDH drinking water standards.

During releases from Ponds A-4, B-5, and C-2 in 1987, water was sampled continuously. The samples were analyzed for plutonium, uranium, americium, tritium, pH, nitrate as N, and nonvolatile suspended solids. Water is also sampled continuously and collected daily from the outfall of Pond C-1 and collected from the Walnut Creek at Indiana Street sampling station when there is flow. Daily samples are taken and analyzed for tritium. The daily samples are composited into weekly samples for plutonium, uranium, and americium analyses. Concentrations of plutonium, uranium, americium, and tritium in water samples from the outfalls of Ponds A-4, B-5, C-1, C-2, and from Walnut Creek at Indiana Street are presented in Tables 11 and 12. All plutonium, uranium, americium, and tritium concentrations at these locations were 2.3 percent or less of the applicable DOE Derived Concentration Guides (DCGs).

A maximum concentration of 7.1 ± 0.08 μCi/mℓ plutonium and 2.1 ± 0.3 μCi/mℓ americium (see

TABLE 12. Tritium Concentrations in Water at the Rocky Flats Plant

Location	Number of Analyses	Tritium Concentration ($\times 10^{-9}$ μCi/mℓ)[a] C_{min}	C_{max}	C_{mean}	Percent of DCG
Pond A-4	21	-700 ± 400[b]	800 ± 400[b]	200 ± 90[c]	0.01
Pond B-5	37	-600 ± 400	1000 ± 400	200 ± 70	0.01
Pond C-1	44	-900 ± 400	800 ± 500	100 ± 60	0.005
Pond C-2	13	-400 ± 400	700 ± 600	300 ± 120	0.02
Walnut Creek at Indiana Street	63	-1000 ± 400	1000 ± 400	400 ± 40	0.02

a. The interim standard calculated Derived Concentration Guide (DCG) for tritium in water available to the members of the public is 2,000,000 × 10^{-9} μCi/mℓ. (See Appendix A.)
b. Calculated as 1.96 standard deviations of the individual measurement.
c. Calculated as 1.96 standard deviations of the mean.

TABLE 13. Uranium Concentrations in the Rocky Flats Plant Raw Water Supply

Location	Number of Analyses	Uranium Concentration ($\times 10^{-9}$ μCi/mℓ)[a] C_{min}	C_{max}	C_{mean}	Percent of DCG
Rocky Flats Raw Water[b]	12	0.3 ± 0.1[c]	2.0 ± 0.1[c]	0.9 ± 0.04[d]	0.2

a. Radiochemically determined as uranium-233, -234, and -238. The interim standard calculated Derived Concentration Guide (DCG) for uranium in water available to members of the public is 500 × 10^{-9} μCi/mℓ. (See Appendix A.)
b. Source of raw water - Ralston Reservoir and South Boulder Diversion Canal.
c. Calculated as 1.96 standard deviations of the individual measurement.
d. Calculated as 1.96 standard deviations of the mean.

Table 11) was determined at the Walnut Creek and Indiana sampling location. Normal sample results were measured for all other sampling locations at the plant site and from reservoir and community samples for the sampling period August 21-28, 1987, during which the maximum concentration was found. The Broomfield and Colorado Department of Health samples taken during the same time frame also produced normal results. There was no indication of sampling or laboratory analytical error in the maximum concentration analysis. The most likely explanation for the elevated concentrations is localized resuspension of small amounts of contaminated soil or sediment into the water samples.

As previously mentioned, surface runoff water from the Rocky Flats Plant passes through Ponds A-4, B-5, and C-2 where the water is sampled and analyzed for radionuclides during the discharge process. During 1987, the cumulative amounts of plutonium from Ponds A-4, B-5, and C-2 were 3.2 × 10^{-6} Ci (1.2 × 10^{5} Bq), 3.5 × 10^{-6} Ci (1.3 × 10^{5} Bq) and 3.4 × 10^{-6} Ci (1.3 × 10^{5} Bq), respectively. The yearly cumulative totals for uranium, were 36.1 × 10^{-4} Ci (1.3 × 10^{8} Bq), 10.4 × 10^{-4} Ci (3.8 × 10^{7} Bq), and 6.2 × 10^{-4} Ci (2.3 × 10^{7} Bq), respectively. The totals for americium were 5.7 × 10^{-6} Ci (2.1 × 10^{5} Bq), 2.4 × 10^{-6} Ci (8.9 × 10^{4} Bq), and 0.6 × 10^{-6} Ci (2.2 × 10^{4} Bq), respectively. Finally, the yearly cumulative totals for tritium from Ponds A-4, B-5, and C-2 were 6.5 × 10^{-2} Ci (2.4 × 10^{9} Bq), 2.1 × 10^{-1} Ci (7.8 × 10^{9} Bq), and 5.2 × 10^{-2} Ci (1.9 × 10^{9} Bq), respectively.

During 1987, Rocky Flats Plant raw water supply was obtained from Ralston Reservoir and from the South Boulder Diversion Canal. Ralston Reservoir water usually contains more natural uranium radioactivity than the water flowing from the South Boulder Diversion Canal. During the year, uranium analyses were performed monthly on samples of Rocky Flats raw water. The uranium concentrations measured during 1987 are presented in Table 13. Uranium concentrations measured

Vols A-4, B-5, C-2

during 1987 in raw water averaged 0.9×10^{-9} μCi/mℓ (0.03 Bq/ℓ) or 0.001 μg/mℓ.

A vegetation control program using chemical herbicides was conducted at the Rocky Flats Plant during 1987. The application was completed by licensed independent contractors using EPA approved chemicals applied strictly according to the manufacturer's label. Rockwell personnel conducted inspections to ensure compliance with the appropriate regulations governing application of herbicides.

Approximately 1,226 gallons (4,640 ℓ) of waste contaminated with polychlorinated biphenyls (PCBs) and low-level radioactivity are stored in approved holding facilities at the Rocky Flats Plant. Some operating transformers contain PCBs, and each is identified, properly labeled, and protected according to EPA regulations. A program is in place to replace all PCB-containing transformers. Analytical results from downstream waters during 1987 showed no concentrations of of PCBs in excess of the analytical detection limit of approximately 1 part per billion.

E. Groundwater Monitoring

As part of the Resource Conservation and Recovery Act (RCRA), two programs involving extensive hydrogeologic, geologic and groundwater quality investigations continued in 1987. The largest program was that of the Remedial Investigations (RI) for high priority areas which includes the 881 Hillside, 903 Pad, Mound, and East Trenches. These investigations are to provide information on the extent and magnitude of groundwater and soil contamination and to evaluate the characteristics of the possible sources. A total of 46 monitoring wells and 52 boreholes were completed as part of this assessment. The remedial investigation field activities began in March and ended in October 1987. Additional investigation activities will commence in the spring of 1988 in order to finalize the source characterization and contaminant delineation. Preliminary Remedial Investigation reports for these areas can be found in the 881 Hillside Remedial Investigation Report (draft), July 1987 and for the 903 Pad, Mound, and East Trenches Remedial Investigation Report (draft), December 1987.

Other field programs operated in 1987 were associated with the RCRA Closure Permit activities for previously used solar evaporation ponds and the present operating landfill. These activities were to characterize the present condition of each regulated unit in order to establish effective RCRA Closure Plans. Installation of 21 wells and the drilling of 19 boreholes for soil analyses were conducted. These field activities were completed in December of 1987. Characterization reports of these sites will be issued July 1988.

Geology—Surficial materials consist of the Rocky Flats Alluvium, alluvial deposits in the valleys and colluvium (slope wash). The Rocky Flats Alluvium is topographically the highest and is the oldest of the alluvial deposits in the vicinity of the plant. (See Figure 9.) The Verdos Alluvium, Slocum Alluvium, Terrace Alluvium, and Recent Alluvium (lowest channel deposits) are found in the drainages and are primarily reworked Rocky Flats Alluvium with the addition of some bedrock material. The Rocky Flats Alluvium is a poorly sorted Quaternary deposit of sand, gravel and cobbles in a clay matrix. Its thickness varies greatly because it was deposited upon an undulating bedrock surface. The thickest portion occurs on the west side of the plant (up to 100 feet) and is thinnest to nonexistent on the east edge of the plant.

Bedrock at Rocky Flats is comprised of two poorly indurated fluvial formations of Cretaceous age, the Arapahoe Formation (Ka) which is immediately beneath the 384 acre security-fenced area of the Plant and the upper Laramie Formation (Klu) which underlies the west buffer zone. The Arapahoe consists of fluvial claystones with interbedded discontinuous lenticular sandstones and siltstones, which are stratigraphically complex. Weathering has penetrated the bedrock 10-40 feet below the surficial material. The Laramie Formation can be separated into two geological units. The upper Laramie consists primarily of fluvial claystone with occasionally encountered thin sandstone lenses. The lower Laramie is comprised of sandstones and siltstones with interbedded claystones. Directly under the

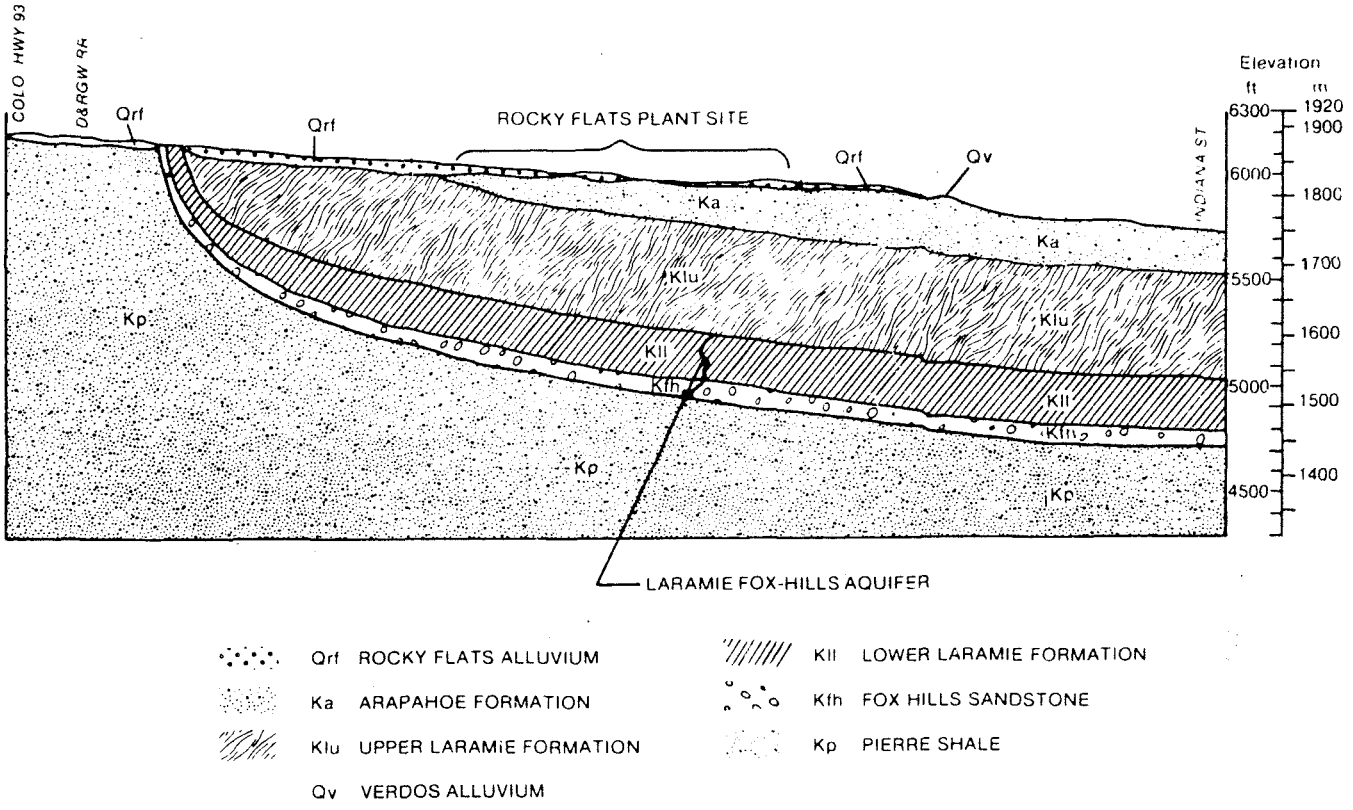


FIGURE 9. Geologic Cross-Section in the Rocky Flats Plant Area

Plant, both formations dip approximately 7 degrees eastward toward the Denver Basin.

Hydrogeology--There are basically two hydraulically connected groundwater flow systems at the Rocky Flats Plant. These occur in the Rocky Flats Alluvium and other surficial materials (including valley fill materials), and in the bedrock, primarily the claystones and sandstones of the Arapahoe Formation.

The shallow groundwater flow system occurs in the Rocky Flats Alluvium and other surficial materials under unconfined conditions. This system is recharged by infiltration from incident precipitation, creeks, ponds, surface water diversion canals and spray evaporation/irrigation systems. Monthly water level measurements (potentiometric conditions) show this system to be quite dynamic, with large fluctuations in response to seasonal and other stresses.

Alluvial wells reveal large areas that develop little or no saturated conditions. These unsaturated conditions can limit the amount of groundwater flow.

Flow direction of water in the alluvial system generally follows topography, to the east and toward drainages. In addition, water flow directions are also controlled by the topography of the bedrock surface beneath the surficial material. Groundwater discharges to the surface environment through evapotranspiration and baseflow to springs and stream channels.

The majority of the groundwater movement in the Arapahoe Formation occurs in the sandstone lenses. Recharge to the sandstone lenses occurs where they are in direct contact with the alluvium (subcrop areas) or by leakage through the weathered claystone. Groundwater flow is easterly to an area of discharge along the South Platte River, in the general area near Fort Lupton, Colorado.

Sampling and Analysis--Quarterly sampling was conducted for selected pre-1986 wells and all of

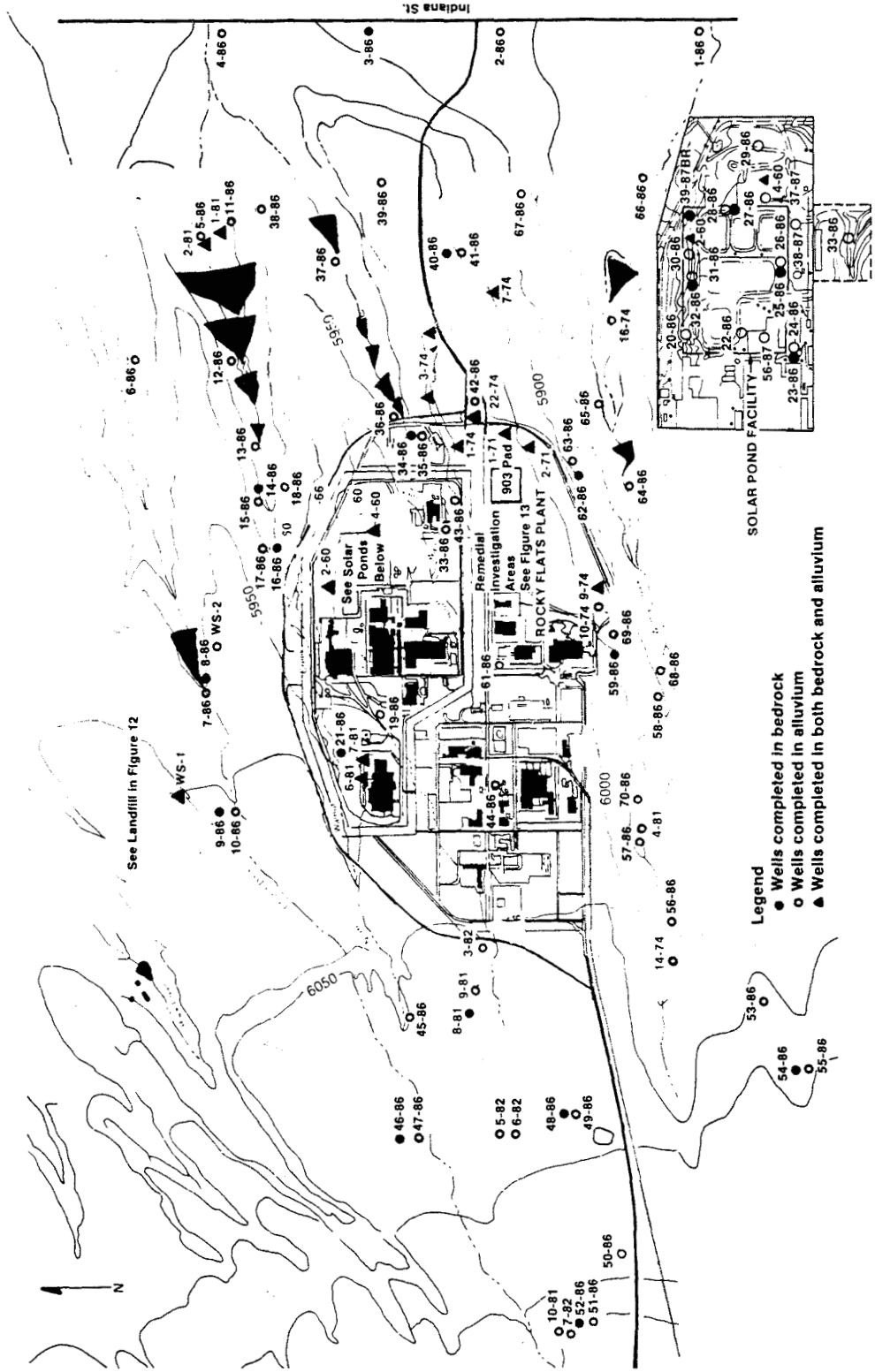


FIGURE 10. Locations of Groundwater Monitoring Wells at Rocky Flats

the wells constructed in 1986. A total of 67 additional wells also were installed and sampled in 1987. These wells were sampled shortly after installation and then were placed into the quarterly monitoring program (see Figures 10 through 12). A total of 159 monitoring wells are currently being sampled quarterly. Groundwater quality parameters analyzed in 1987 are shown in Table 14. All of the fourth quarter data was not available during preparation of this report. Due to the amount of data involved, only those volatile organic compounds (VOCs) and radionuclides most prevalent among the areas are presented. Analytical results for these parameters are found in Tables 15 through 24. Duplicate results are frequently shown in the tables. These are part of the Quality Assurance and Quality Control (QA/QC) protocol of the groundwater monitoring program.

Maximum concentrations of all volatile organic compounds (VOCs) identified in the groundwater are presented in Table 16. The unit of measurement for VOCs is micrograms per liter ($\mu g/\ell$). This is approximately equivalent to parts per billion (ppb). Maximum concentrations of the radionuclides analyzed are presented in Table 15. For perspective Derived Concentration Guides (DCGs) (see Appendix A) for water discharged to uncontrolled areas are also presented in Table 15. However, the DOE offsite DCGs are not applicable to radionuclides in onsite groundwater.

Data Analysis--Groundwater quality data indicate VOC contamination exists in the alluvium of each of the high priority remedial investigation areas. The extent of contamination is well within the plant boundary. Relative concentrations of the contaminants and major ion chemistry, together with the hydrogeologic characteristics, assist in the differentiation of the various plumes. Due to the close proximity of some areas to each other, the contamination converges in several locations. The plume with the largest areal extent emanates from the 903 Pad Area. It extends southeasterly, to the rifle range, and in the south to the interceptor ditch which runs parallel to Woman Creek. Samples taken from wells and surface water at Woman Creek do not show any VOC contamination. (See Figure 11.)

TABLE 14. Groundwater Monitoring Parameters

Indicators
Temperature
pH
Specific Conductance
Metals
EPA Hazardous Substances List Metals (including 26 different metals)
Lithium*
Hexavalent Chromium*
Anions
Bicarbonate
Carbonate
Chloride
Cyanide
Nitrate
Sulfate
Organics
EPA Hazardous Substances List Volatile Organic Componds (including 34 different VOCs)
Radionuclides
Gross Alpha
Gross Beta
Uranium-233, -234, -238
Americium-241
Plutonium-239, -240
Tritium

* Sampled initially at remedial investigation monitoring wells.

VOC contamination in the alluvium at the 903 Pad Area is comprised of Tetrachloroethylene (PCE), Trichloroethylene (TCE), and Carbon Tetrachloride (CCl_4). Several RCRA-designated Solid Waste Management Units (SWMUs) located at and southeast of the 903 Pad have released contamination of varying composition and concentrations. The maximum concentration is that of TCE in well 2-71 28,800 $\mu g/\ell$.

At the 881 Hillside, VOC contamination is generally isolated in a small area near one of the SWMUs which was historically used for drum storage. Elevated VOC concentrations are primarily found in wells 9-74 and 10-74. The VOCs found are PCE; TCE; CCl_4; 1,1-DCE; 1,1,1-TCA; trans-1,2-DCE; 1,1-DCA; 1,2-DCA; and chloroform ($CHCl_3$) (see Table 16). The highest concentrations consisted of 28,000 $\mu g/\ell$ CCl_4 and 72,000 $\mu g/\ell$ TCE in well

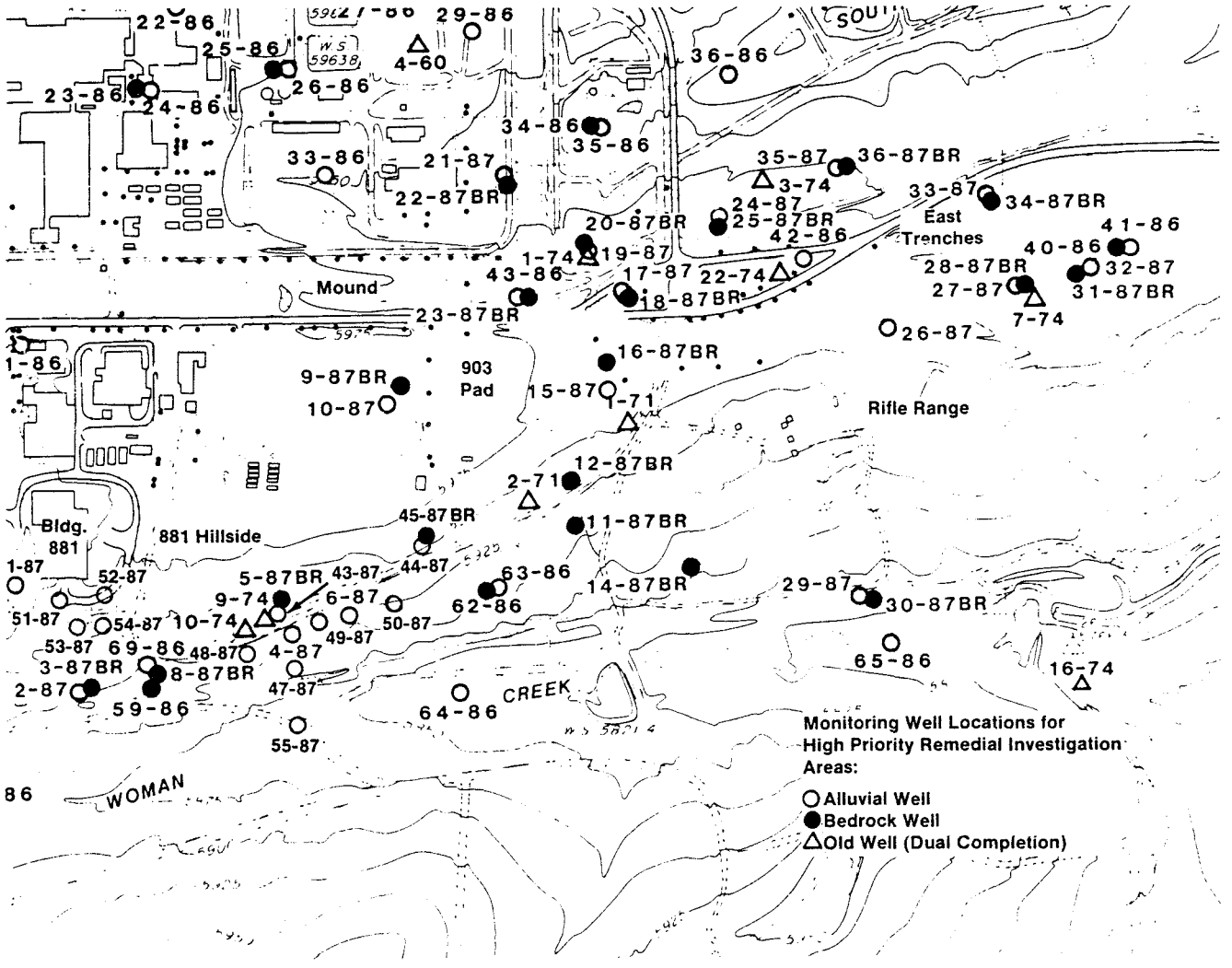


FIGURE 11. Monitoring Well Locations for High Priority Remedial Investigation Areas

9-74. All radionuclides are below the Environmental Protection Agency (EPA) drinking water standards.(US76a)

Alluvial contamination at the Mound consists of the VOCs PCE; TCE; CCl_4; 1,1-DCE; trans-1,2-DCE; 1,2-DCA; 1,1,1-TCA; and $CHCl_3$. This plume extends eastward to the East Trenches and north to South Walnut Creek where 1600 $\mu g/\ell$ of trans-1,2-DCE was found in well 35-86. Samples from well 1-74 are several orders of magnitude higher for PCE and TCE having values of 528,000 and 18,000 $\mu g/\ell$, respectively. Results close to the detection limit of TCE were found in some samples from well 36-86.

Alluvial groundwater quality at the East Trenches indicates relatively moderate VOC concentrations at the west end due to the close proximity to the Mound and 903 Areas. The same VOCs—PCE, TCE, and CCl_4 (the maximum VOC concentration was 4835 $\mu g/\ell$ for CCl_4)—are found at well 42-86. The extent of the plume in the alluvium does not appear extensive. Concentrations at the east end are low to non-detectable. However, additional work is needed in this area to fully characterize the extent of the plume.

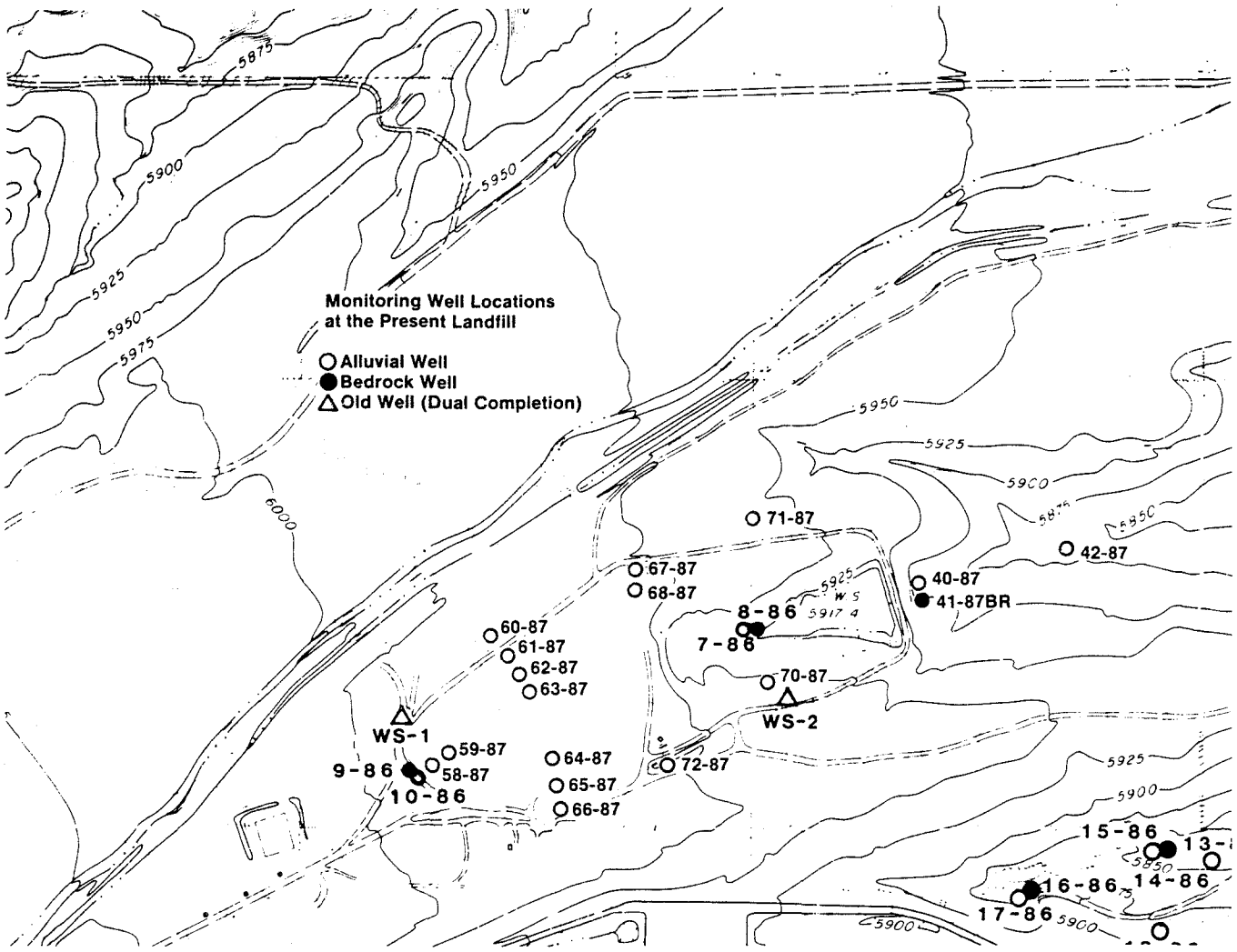


FIGURE 12. Monitoring Well Locations at the Present Landfill

Groundwater quality immediately adjacent to the solar evaporation ponds contains elevated concentrations of nitrates and radionuclides–specifically, uranium isotopes and tritium. Concentrations are highest in well 28-86 and 30-86. A rather sharp chemical gradient exists on the south and east sides of the pond area. However, on the north side of the ponds, concentrations of 24 X 10^{-9} μCi/mℓ (8.9 X 10^{-1} Bq/ℓ) of U-233 and U-234 and 19 X 10^{-9} μCi/mℓ (7.0 X 10^{-1} Bq/ℓ) of U-238, were found. Elevated nitrate concentrations, at 54 mg/ℓ of nitrate as N, were found in well 15-86. New alluvial and bedrock groundwater quality wells at the current Landfill appear unaffected by past operations. This area and the West Spray Field are undergoing RCRA closure permit activities, and more investigations are continuing.

Bedrock contamination consists of VOCs which occur in two areas, the 903 Pad Area and East Trenches. This contamination is found in the lenticular sandstones of the Arapahoe Formation. The concentrations of VOC in the bedrock indicate these sandstones are being recharged from the overlying alluvial system. Additional investigations on the stratigraphic correlation and lateral extent of the sandstones are needed to delineate the VOC contamination.

TABLE 15. Summary of Plutonium, Uranium, Americium, and Tritium Concentration Ranges in Groundwater at Rocky Flats Plant

	Radioactivity Concentrations ($\times 10^{-9}$ μCi/mℓ)[a]		C_{max} Percent of DCG[d]	C_{max} Well Number	DCG ($\times 10^{-9}$ μCi/mℓ)
	(C_{min}[b])	(C_{max}[c])			
Plutonium-239, -240	-1.6 ± 6.0	4.7 ± 1.8[e]	1.6	45-86	300
Americium-241	-0.4 ± 1.6	2.3 ± 2.9[e]	3.8	68-86	60
Uranium-233, -234	0.4 ± 1.1	1,000 ± 300	200	28-86	500
Uranium-235	-0.2 ± 0.2	47 ± 15	7.8	28-86	600
Uranium-238	-0.9 ± 1.0	750 ± 200	125	28-86	600
Tritium	<515	85,000	4.3	30-86	2,000,000

a. To obtain the proper concentration, multiply the numbers in the table by 10^{-9} μCi/mℓ. For example, the minimum plutonium-239, -240 concentration is -1.6×10^{-9} μCi/mℓ.
b. C_{min} is the minimum measured concentration.
c. C_{max} is the maximum measured concentration.
d. Comparisons with Derived Concentration Guides are presented for perspective only. The DOE offsite DCGs are not applicable to radioactivity concentrations in onsite groundwater.
e. Well was dry in November 1987, when attempt was made to re-sample in order to verify this value.

TABLE 16. *Maximum* Concentrations for Volatile Organic Compounds

Compound	Maximum	Well Number	Quarter
Tetrachloroethylene (PCE)	528,000 μg/ℓ	1-74	2
Trichloroethylene (TEC)	118,298 μg/ℓ	36-87	4
1,1-Dichloroethylene (1,1-DCE)	48,000 μg/ℓ	9-74	2
1,1,1-Trichloroethane (1,1,1-TCA)	30,250 μg/ℓ	9-74	2
Carbon Tetrachloride (CCl_4)	28,000 μg/ℓ	9-74	2
1,2-Dichloroethane (1,2-DCA)	16,000 μg/ℓ	9-74	2
Chloroform ($CHCl_3$)	5,427 μg/ℓ	36-87	4
Trans-1,2-Dichloroethylene (Trans-1,2-DCE)	5,070 μg/ℓ	43-87	4
1,1-Dichloroethane (1,1-DCA)	342 μg/ℓ	43-87	4

The extent of bedrock contamination at the trenches is uncertain at this time. The one sample available to date from well 36-87 shows concentrations of PCE; TCE; 1,1-DCE; 1,1,1-TCA; and CCl_4 at 4654, 118298, 1044, 1472, and 3673 μg/ℓ, respectively. Well 25-87, located on the west end, contains relatively low concentrations of PCE, TCE, and CCl_4 at concentrations of 528, 56, and 75 μg/ℓ, respectively.

VOCs were also detected in the bedrock groundwater below the 903 Pad in wells 12-87, 11-87, and 14-87. The highest concentrations were that of TCE at concentrations of 3570, 595, and 109 μg/ℓ for each well, respectively.

Future Monitoring—Groundwater monitoring will continue on a quarterly basis for 1988. Analytical parameters will be the same as those given in Table 14. Monthly water level measurements will also continue in order to better characterize flow patterns.

Additional phases of the remedial investigations for the high priority areas and RCRA Closure activities will commence in the spring of 1988. Remedial Investigations of the low priority sites will begin in the autum of 1988. These investigations will further assess the facility's impact, if any, on the groundwater systems. Feasibility studies have initiated the development and selection of effective

TABLE 17. 1987 Groundwater Quarterly Sampling Program Plutonium-239, -240 ($\times 10^{-9}$ μCi/mℓ)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1-71	0.91 ± 0.63	0.0 ± 0.59	PS	0.00 ± 0.07
	0.05 ± 1.5			
1-74	0.00 ± 0.65	0.9 ± 1.1	0.0 ± 0.7	0.01 ± 0.09
1-81	0.00 ± 0.69	0.00 ± 0.96	-0.1 ± 1.3	0.00 ± 0.16
1-86	2.1 ± 1.4	1.1 ± 1.1	-0.24 ± 0.65	PS
1-87	NC			
2-60	0.70 ± 0.96	PS	0.5 ± 1.8	0.00 ± 0.20
2-71	1.9 ± 1.0	0.02 ± 0.76	NA	0.00 ± 0.15
	0.22 ± 0.95			
2-81	0.0 ± 0.85	0.8 ± 1.3	0.0 ± 1.1	0.00 ± 0.17
2-86	0.72 ± 0.93	0.9 ± 1.1	-0.1 ± 1.0	Dry
2-87	NC	0.9 ± 1.1	0.42 ± 0.81	0.04 ± 0.09
		PS		
3-74	0.00 ± 0.67	0.00 ± 0.79	0.10 ± 0.69	0.00 ± 0.10
			PS	
3-82	0.10 ± 0.77	0.0 ± 0.6	0.05 ± 0.55	0.00 ± 0.18
3-86	0.00 ± 0.70	0.00 ± 0.59	-0.32 ± 0.68	0.00 ± 0.14
3-87	NC	PS	0.15 ± 0.98	0.05 ± 0.11
4-60	0.79 ± 0.89	0.00 ± 0.66	-0.3 ± 1.5	0.00 ± 0.15
4-81	PS	Dry	PS	Dry
4-86	Dry	Dry	PS	Dry
4-87	0.00 ± 0.55	Dry	0.14 ± 0.73	0.06 ± 0.14
5-82	0.00 ± 0.68	0.0 ± 0.5	0.11 ± 0.76	0.00 ± 0.14
5-86	0.7 ± 1.1	0.0 ± 0.6	-0.32 ± 0.97	Dry
5-87	NC	0.00 ± 0.55	0.6 ± 1.4	0.06 ± 0.12
6-81	PS	0.07 ± 0.71	-0.3 ± 2.8	PS
6-82	0.44 ± 0.84	0.0 ± 0.8	-0.32 ± 0.60	0.00 ± 0.17
6-86	0.0 ± 6.8	PS	PS	Dry
6-87	NC	NC	-0.23 ± 0.59	PS
			PS	
7-74	0.10 ± 0.61	0.03 ± 0.76	0.0 ± 0.6	0.00 ± 0.20
			PS	
7-81	PS	PS	PS	PS
7-82	Dry	Dry	Dry	PS
7-86	Dry	Dry	PS	Dry
8-81	0.25 ± 0.82	0.00 ± 0.66	-0.32 ± 0.55	0.00 ± 0.18
8-86	0.21 ± 0.85	0.05 ± 0.62	PS	0.00 ± 0.16
8-87	NC	1.7 ± 1.9	0.00 ± 0.46	PS
9-74	0.28 ± 0.59	0.19 ± 0.75	0.0 ± 1.1	0.00 ± 0.11
	0.0 ± 1.1			PS
9-81	0.00 ± 0.63	0.00 ± 0.59	-0.13 ± 0.58	0.00 ± 0.17
9-86	0.6 ± 1.2	0.00 ± 0.65	-0.3 ± 1.4	0.00 ± 0.14
9-87	NC	NC	NC	0.08 ± 0.10
				PS
10-74	Dry	0.02 ± 0.79	PS	PS
10-81	0.10 ± 0.70	0.32 ± 0.77	-0.32 ± 0.46	0.00 ± 0.14
10-86	0.13 ± 0.74	0.00 ± 0.64	-0.30 ± 0.61	0.00 ± 0.15
10-87	NC	NC	NA	NA
11-86	NA	0.0 ± 0.7	-0.3 ± 1.6	Dry
11-87	NC	NC	0.20 ± 0.07	NA
			PS	
12-85	0.00 ± 0.78	0.5 ± 1.1	0.2 ± 1.5	Dry
12-87	NC	NC	NA	NA
13-86	PS	PS	PS	Dry

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 17. 1987 Groundwater Quarterly Sampling Program Plutonium-239, -240 ($\times 10^{-9}$ μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
14-86	1.2 ± 0.9	0.0 ± 0.8	0.25 ± 0.82	0.00 ± 0.37
14-87	NC	NC	NA	0.00 ± 0.15
			NA	
15-86	0.00 ± 0.55	0.00 ± 0.69	-0.32 ± 0.46	0.00 ± 0.24
15-87	NC	NC	NA	0.00 ± 0.16
16-74	Dry	Dry	PS	Dry
16-86	0.3 ± 1.1	0.00 ± 0.66	-0.03 ± 0.21	0.00 ± 0.18
16-87	NC	NC	NA	0.05 ± 0.09
17-86	0.0 ± 0.97	0.6 ± 1.5	-0.03 ± 0.17	0.00 ± 0.37
17-87	NC	NC	NA	NA
18-86	Dry	Dry	PS	Dry
18-87	NC	NC	NC	NC
19-86	0.3 ± 1.0	0.0 ± 1.2	PS	0.00 ± 0.15
		0.00 ± 0.61	0.85 ± 0.76	
19-87	NC	NC	NA	NA
20-86	Dry	Dry	PS	Dry
20-87	NC	NC	NC	PS
21-86	0.73 ± 0.96	0.00 ± 0.67	-0.06 ± 0.66	0.00 ± 0.17
21-87	NC	NC	NC	NA
22-74	0.00 ± 0.63	0.00 ± 0.70	-0.23 ± 0.93	0.00 ± 0.12
22-86	4.6 ± 2.3	0.6 ± 1.0	-0.32 ± 0.85	0.00 ± 0.16
22-87	NC	NC	NA	NA
23-86	Dry	PS	PS	0.00 ± 0.16
23-87	NC	NC	PS	NA
24-86	Dry	Dry	PS	Dry
24-87	NC	NC	NA	NA
25-86	0.08 ± 0.80	0.00 ± 0.79	0.29 ± 0.77	0.00 ± 0.24
25-87	NC	NC	PS	NA
26-86	0.18 ± 0.95	Dry	0.07 ± 0.58	Dry
26-87	NC	NC	NC	NA
27-86	0.00 ± 0.79	0.5 ± 0.7	NA	0.00 ± 0.16
	0.00 ± 0.94			
27-87	NC	NC	NA	NA
28-86	0.0 ± 1.4	0.15 ± 0.72	PS	Dry
28-87	NC	NC	NA	NA
29-86	Dry	Dry	PS	Dry
29-87	NC	NC	NC	NA
30-86	0.0 ± 3.8	0.00 ± 0.55	-0.2 ± 1.1	0.00 ± 0.37
	0.0 ± 1.9			
30-87	NC	NC	NC	NA
31-86	Dry	Dry	PS	Dry
31-87	NC	NC	NA	NA
32-86	0.0 ± 1.3	0.00 ± 0.67	0.2 ± 1.0	NA
	0.24 ± 0.70			
32-87	NC	NC	NA	NA
33-86	Dry	Dry	PS	Dry
33-87	NC	NC	NA	NA
34-86	0.00 ± 0.92	0.98 ± 0.99	-0.06 ± 0.72	NA
	0.0 ± 1.5			
34-87	NC	NC	NA	NA
35-86	0.24 ± 0.89	0.0 ± 0.72	-0.32 ± 0.96	NA
35-87	NC	NC	NA	NA
36-86	PS	PS	PS	Dry
36-87	NC	NC	NA	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 17. 1987 Groundwater Quarterly Sampling Program Plutonium-239, -240 ($\times 10^{-9}$ μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
37-86	Dry	Dry	PS	Dry
37-87	NC	NC	NC	Dry
38-86	NA	2.6 ± 1.2	1.9 ± 8.8	NA
39-86	0.00 ± 0.57	0.21 ± 0.73	PS	NA
39-87	NC	NC	NC	NA
40-86	0.24 ± 0.73	PS	PS	NA
40-87	NC	NC	PS	Dry
41-86	0.00 ± 0.85	NA	-0.04 ± 0.66	NA
				NA
41-87	NC	NC	NA	NA
42-86	0.12 ± 0.48	0.0 ± 0.55	0.36 ± 0.74	NA
42-87	NC	PS	PS	Dry
43-86	0.23 ± 0.59	0.00 ± 0.65	-0.20 ± 0.85	0.00 ± 0.16
43-87	NC	NC	NC	NA
44-86	0.00 ± 0.55	0.0 ± 0.7	-0.32 ± 0.49	NA
44-87	NC	NC	NA	NA
45-86	4.7 ± 1.8	0.00 ± 0.68	0.10 ± 0.86	NA
45-87	NC	NC	NC	0.00 ± 0.12
46-86	0.00 ± 0.77	0.0 ± 0.7	0.01 ± 0.92	-0.03 ± 0.04
47-86	0.08 ± 0.71	0.0 ± 0.7	0.11 ± 0.78	0.11 ± 0.14
47-87	NC	NC	NC	NA
48-86	0 0 ± 1.1	0.03 ± 0.63	-0.32 ± 0.78	0.00 ± 0.14
48-87	NC	NC	NC	PS
49-86	0.0 ± 2.2	0.42 ± 0.82	-0.32 ± 0.64	0.00 ± 0.18
49-87	NC	NC	NC	NA
50-86	1.0 ± 1.0	0.0 ± 0.67	-0.32 ± 0.65	0.00 ± 0.10
50-87	NC	NC	NC	PS
51-86	0.0 ± 0.71	0.3 ± 0.8	-1.6 ± 6.0	0.00 ± 0.14
		0.3 ± 0.8		
51-87	NC	NC	NC	NA
52-86	0.12 ± 0.67	0.3 ± 0.7	1.8 ± 1.3	0.00 ± 0.03
52-87	NC	NC	NC	0.00 ± 0.28
53-87	Dry	Dry	PS	PS
54-86	0.0 ± 1.1	0.008 ± 0.75	-0.08 ± 0.60	0.00 ± 0.22
			PS	
54-87	NC	NC	NC	PS
55-86	0.03 ± 0.65	0.07 ± 0.82	-0.14 ± 0.53	0.00 ± 0.06
			PS	
55-87	NC	NC	NA	NA
56-86	0.28 ± 0.70	0.003 ± 0.76	0.00 ± 0.46	0.00 ± 0.05
56-87	NC	NC	NC	Dry
57-86	0.00 ± 0.94	Dry	PS	PS
58-86	Dry	Dry	PS	PS
58-87	NC	NC	NC	NA
59-86	0.9 ± 1.1	0.00 ± 0.64	0.07 ± 0.71	0.07 ± 0.12
	0.00 ± 0.84			
59-87	NC	NC	NC	NA
60-87	NC	NC	NC	NA
61-86	0.40 ± 0.69	0.00 ± 0.74	0.3 ± 1.3	PS
62-86	0.0 ± 1.1	0.04 ± 0.76	0.06 ± 0.71	0.04 ± 0.09
	0.0 ± 1.3			
62-87	NC	NC	NC	NA
63-86	Dry	Dry	PS	PS
63-87	NC	NC	NC	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 17. 1987 Groundwater Quarterly Sampling Program Plutonium-239, -240 ($\times 10^{-9}$ μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
64-86	0.2 ± 1.1	Dry	PS	PS
64-87	NC	NC	NC	NA
65-86	0.00 ± 0.65	0.16 ± 0.78	PS -0.03 ± 0.16	PS
65-87	NC	NC	NC	NA
66-86	0.00 ± 0.55	0.00 ± 0.63	PS	Dry
66-87	NC	NC	NC	NA
67-86	0.00 ± 0.74	0.00 ± 0.62	0.25 ± 0.80	Dry
67-87	NC	NC	NC	NA
68-86	0.00 ± 0.85	0.00 ± 0.64	-0.25 ± 0.66	Dry
68-87	NC	NC	NC	NA
69-86	0.0 ± 2.1	0.0 ± 0.6	-0.02 ± 0.69	0.00 ± 0.22
70-86	0.00 ± 0.61	0.00 ± 0.88	-0.05 ± 0.50	0.00 ± 0.17
70-87	NC	NC	NC	NA
71-87	NC	NC	NC	NA
72-87	NC	NC	NC	NA
WS-01	NA	NA	-0.13 ± 0.69	0.00 ± 0.14
WS-02	NA	0.03 ± 0.74 0.00 ± 0.55	0.13 ± 0.83	PS

1987 Summary

Minimum Value:	-1.6 ± 6.0	(Well 51-86	Quarter 3)
Maximum Value:	4.7 ± 1.8	(Well 45-86	Quarter 1)

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 18. 1987 Groundwater Quarterly Sampling Program Americium-241 ($\times 10^{-9}$ μCi/mℓ)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1-71	0.0 ± 1.8 0.0 ± 2.6	0.0 ± 1.3	1.50 ± 1.50	0.00 ± 0.43
1-74	0.0 ± 1.2	0.0 ± 1.2	0.16 ± 0.58	0.00 ± 0.58
1-81	0.0 ± 1.2	0.0 ± 1.3	0.0 ± 1.0	0.00 ± 0.66
1-86	0.0 ± 1.3	0.0 ± 1.2	-0.04 ± 0.18	PS
1-87	NC	Dry	Dry	Dry
2-60	PS	PS	-0.04 ± 0.50	PS
2-71	0.4 ± 4.0 0.0 ± 3.7	0.0 ± 1.2	NA	0.00 ± 0.02
2-81	0.8 ± 1.8	0.0 ± 2.3	0.14 ± 0.37	NA
2-86	0.80 ± 0.96	0.0 ± 1.7	NA	Dry
2-87	NC	0.0 ± 6.0 PS	-0.04 ± 0.75	0.00 ± 0.20
3-74	0.0 ± 3.2	0.0 ± 1.2	-0.04 ± 0.28 PS	0.00 ± 0.08
3-82	0.0 ± 1.8	0.0 ± 1.2	-0.04 ± 0.18	0.00 ± 0.13
3-86	0.0 ± 2.2	0.1 ± 1.5	0.00 ± 0.40	NA
3-87	NC	PS 0.0 ± 4.1	0.25 ± 0.32	0.00 ± 0.08
4-60	NA	0.0 ± 1.4	0.0 ± 1.6	0.00 ± 0.22
4-81	PS	Dry	PS	Dry
4-86	Dry	Dry	PS	Dry
4-87	0.0 ± 2.6	Dry	0.70 ± 0.86	0.02 ± 0.07
5-82	0.0 ± 1.2	0.0 ± 1.8	0.04 ± 0.62	NA
5-86	0.0 ± 1.3	NA	NA	Dry
5-87	NC	0.0 ± 3.0	-0.04 ± 1.41	0.00 ± 0.12
6-81	PS	0.0 ± 1.6	-0.04 ± 0.18	PS
6-82	0.0 ± 2.6	0.0 ± 1.2	-0.04 ± 0.43	0.00 ± 0.20
6-86	PS	PS	PS	Dry
6-87	NC	NC	-0.04 ± 1.6 PS	PS
7-74	0.0 ± 1.2	0.0 ± 1.2	0.13 ± 0.35 PS	0.01 ± 0.07
7-81	PS	PS	PS	PS
7-82	Dry	Dry	Dry	PS
7-86	Dry	Dry	PS	Dry
8-81	NA	0.0 ± 1.5	-0.04 ± 0.65	0.07 ± 0.10
8-86	0.0 ± 1.2	0.0 ± 1.2	PS	0.02 ± 0.10
8-87	NC	0.0 ± 1.5	-0.04 ± 0.18	PS
9-74	NA 0.0 ± 3.5	0.0 ± 1.2	NA	0.00 ± 0.03 PS
9-81	0.0 ± 1.3	0.0 ± 1.2	0.16 ± 0.38	0.00 ± 0.21
9-86	0.0 ± 1.2	0.0 ± 1.2	0.19 ± 0.29	0.00 ± 0.12
9-87	NC	NC	NA	0.00 ± 0.06
10-74	Dry	0.0 ± 1.2	PS	PS
10-81	0.0 ± 1.2	0.0 ± 1.2	-0.04 ± 0.56	0.00 ± 0.47
10-86	0.0 ± 1.5	0.0 ± 1.3	0.0 ± 1.4	NA
10-87	NC	NC	Dry	Dry
11-86	0.0 ± 2.7	0.6 ± 6.4	-0.04 ± 0.81 PS	Dry
11-87	NC	NC	0.06 ± 0.05	NA
12-86	0.0 ± 1.8	0.4 ± 1.5	-0.4 ± 5.0	Dry
12-87	NC	NC	NA	NA
13-86	PS	PS	PS	Dry

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 18. 1987 Groundwater Quarterly Sampling Program Americium-241 ($\times 10^{-9}$ μCi/mℓ)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
14-86	0.0 ± 1.2	0.0 ± 1.2	0.04 ± 0.40	0.00 ± 0.13
	PS			
14-87	NC	NC	NA	0.00 ± 0.22
15-86	0.0 ± 2.1	0.0 ± 1.3	0.05 ± 0.74	0.00 ± 0.18
15-87	NC	NC	NA	0.00 ± 0.25
				PS
16-74	Dry	Dry	PS	Dry
16-86	0.4 ± 1.6	0.0 ± 1.3	0.10 ± 0.33	NA
16-87	NC	NC	NA	0.01 ± 0.07
17-86	0.0 ± 1.5	0.0 ± 1.2	-0.04 ± 0.67	0.00 ± 0.41
17-87	NC	NC	NC	NA
18-86	Dry	Dry	PS	Dry
18-87	NC	NC	NA	NA
19-86	0.0 ± 2.0	0.0 ± 1.4	PS	0.11 ± 0.16
		0.0 ± 1.5	-0.04 ± 0.18	
19-87	NC	NC	NA	NA
20-86	Dry	Dry	PS	Dry
20-87	NC	NC	NC	PS
21-86	0.0 ± 1.4	0.0 ± 1.8	-0.04 ± 0.23	0.00 ± 0.13
21-87	NC	NC	NC	NA
22-74	NA	0.0 ± 1.2	1.4 ± 5.2	0.00 ± 0.44
22-86	0.0 ± 1.8	0.0 ± 1.5	-0.04 ± 0.18	0.16 ± 0.18
22-87	NC	NC	NC	NA
23-86	NA	PS	PS	0.01 ± 0.11
23-87	NC	NC	NA	NA
24-86	Dry	Dry	PS	Dry
24-87	NC	NC	NA	NA
25-86	0.0 ± 8.4	0.0 ± 1.3	-0.04 ± 0.18	0.00 ± 0.10
25-87	NC	NC	NA	NA
26-86	NA	Dry	-0.04 ± 0.60	Dry
26-87	NC	NC	NC	NA
27-86	0.2 ± 1.9	0.2 ± 1.2	NA	0.00 ± 0.69
27-87	NC	NC	NC	NA
28-86	0.0 ± 5.4	0.0 ± 1.2	PS	Dry
28-87	NC	NC	NC	NA
29-86	Dry	Dry	PS	Dry
29-87	NC	NC	NC	NA
30-86	0.0 ± 1.2	0.0 ± 1.3	-0.04 ± 0.96	NA
	1.1 ± 9.9			
30-87	NC	NC	NC	0.17 ± 0.12
31-86	Dry	Dry	PS	Dry
31-87	NC	NC	NC	NA
32-86	0.0 ± 1.2	0.0 ± 1.2	-0.04 ± 0.26	0.00 ± 0.14
	0.0 ± 1.8			
32-87	NC	NC	NC	NA
33-86	Dry	Dry	PS	Dry
33-87	NC	NC	NA	NA
34-86	0.0 ± 2.2	0.0 ± 1.8	-0.4 ± 5.5	0.00 ± 0.09
34-87	NC	NC	NA	NA
35-86	0.0 ± 1.3	0.0 ± 1.2	0.9 ± 6.7	0.00 ± 0.31
35-87	NC	NC	NA	NA
36-86	PS	PS	PS	Dry
36-87	NC	NC	NA	NA
37-86	Dry	Dry	PS	Dry
37-87	NC	NC	NC	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 18. 1987 Groundwater Quarterly Sampling Program Americium-241 ($\times 10^{-9}$ μCi/mℓ)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
38-86	0.0 ± 8.5	0.7 ± 1.8	NA	Dry
38-87	NC	NC	NC	NA
39-86	0.0 ± 2.6	0.0 ± 1.2	PS	0.00 ± 0.10
			0.38 ± 0.53	
39-87	NC	NC	NA	NA
40-86	1.0 ± 4.6	PS	PS	0.00 ± 1.6
40-87	NC	NC	PS	Dry
41-86	NA	0.0 ± 1.2	0.27 ± 0.57	0.00 ± 0.15
41-87	NC	NC	NA	NA
			PS	0.00 ± 0.32
42-86	0.3 ± 4.2	0.00 ± 0.12	0.0 ± 2.8	0.00 ± 0.06
			PS	NA
42-87	NC	PS	PS	Dry
43-86	0.0 ± 1.4	0.00 ± 0.12	0.11 ± 0.32	NA
43-87	NC	NC	NC	NA
44-86	0.0 ± 1.3	0.0 ± 1.7	0.0 ± 1.5	0.00 ± 0.80
44-87	NC	NC	NA	NA
45-86	0.0 ± 1.4	0.0 ± 1.5	0.69 ± 0.91	0.00 ± 0.44
45-87	NC	NC	NC	0.0 ± 1.4
46-86	0.0 ± 1.4	0.0 ± 1.2	-0.04 ± 0.38	-0.020 ± 0.037
				0.24 ± 0.71
47-86	0.0 ± 1.5	0.0 ± 1.2	-0.04 ± 0.82	0.00 ± 0.05
47-87	NC	NC	NC	PS
48-86	0.0 ± 2.3	0.0 ± 1.2	0.03 ± 0.37	0.00 ± 0.43
48-87	NC	NC	NC	PS
49-86	0.0 ± 4.4	0.0 ± 1.3	0.03 ± 0.45	NA
49-87	NC	NC	NC	NA
50-86	0.0 ± 2.0	0.0 ± 1.2	-0.04 ± 0.43	0.00 ± 0.19
50-87	NC	NC	NC	NA
51-86	0.0 ± 1.2	0.0 ± 1.3	-0.04 ± 0.47	0.00 ± 0.19
		0.0 ± 1.3		PS
51-87	NC	NC	NC	NA
52-86	0.0 ± 2.1	0.0 ± 1.2	NA	0.00 ± 0.02
52-87	NC	NC	NC	0.00 ± 0.33
53-86	Dry	Dry	PS	PS
53-87	NC	NC	NC	PS
54-86	0.0 ± 1.2	0.9 ± 3.7	-0.04 ± 0.60	0.00 ± 0.34
54-87	NC	NC	NC	PS
55-86	0.0 ± 4.2	0.0 ± 1.2	-0.04 ± 0.44	PS
55-87	NC	NC	PS	0.00 ± 0.16
56-86	0.0 ± 1.3	0.0 ± 1.2	-0.04 ± 0.59	0.00 ± 0.17
56-87	NC	NC	NC	Dry
57-86	0.0 ± 2.5	Dry	PS	PS
58-86	Dry	Dry	PS	PS
58-87	NC	NC	NC	NA
59-86	0.0 ± 1.3	0.0 ± 1.3	NA	0.03 ± 0.11
	0.0 ± 1.6			
59-87	NC	NC	NC	NA
60-87	NC	NC	NC	NA
61-87	NC	NC	NC	NA
62-86	0.0 ± 1.3	0.0 ± 1.2	0.0 ± 0.6	0.00 ± 0.03
	0.0 ± 1.4			
62-87	NC	NC	NC	NA
63-86	Dry	Dry	PS	PS
63-87	NC	NC	NC	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 18. 1987 Groundwater Quarterly Sampling Program Americium-241 ($\times 10^{-9}$ μCi/mℓ)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
64-86	0.0 ± 1.4	PS	NA	PS
64-87	NC	NC	NC	NA
65-86	0.0 ± 1.3	0.0 ± 1.2	PS	PS
			0.02 ± 0.32	
65-87	NC	NC	NC	NA
66-86	0.0 ± 1.2	0.0 ± 1.3	PS	Dry
66-87	NC	NC	NC	NA
67-86	0.6 ± 1.4	0.0 ± 1.2	0.6 ± 1.4	Dry
67-87	NC	NC	NC	NA
68-86	2.3 ± 2.9	0.0 ± 1.2	0.26 ± 0.61	Dry
68-87	NC	NC	NC	NA
69-86	0.0 ± 1.3	0.0 ± 1.8	0.5 ± 2.5	0.00 ± 0.05
70-86	0.0 ± 1.8	0.0 ± 1.5	0.74 ± 0.75	0.00 ± 0.34
70-87	NC	NC	NC	NA
71-87	NC	NC	NC	NA
72-87	NC	NC	NC	NA
WS-01	NA	NA	0.0 ± 2.4	0.0 ± 1.5
WS-02	NA	0.0 ± 1.4	NA	PS
		0.0 ± 1.7		

1987 Summary

Minimum Value: -0.4 ± 1.6 (Well 6-87 Quarter 3)

Maximum Value: 2.3 ± 2.9 (Well 68-86 Quarter 1)

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 19. 1987 Groundwater Quarterly Sampling Program Uranium-233, -234 ($\times 10^{-9}$ μCi/mℓ)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1-71	5.4 ± 1.2	4.9 ± 1.1	6.3 ± 1.6	2.0 ± 0.3
	2.0 ± 1.1			
1-74	1.6 ± 1.4	4.4 ± 1.3	2.0 ± 1.3	1.8 ± 0.8
1-81	2.0 ± 1.6	3.2 ± 1.0	0.9 ± 1.5	0.90 ± 0.19
1-86	1.2 ± 1.0	0.26 ± 0.66	0.0 ± 1.0	PS
1-87	NC	Dry	Dry	Dry
2-60	26 ± 6	PS	15.0 ± 8.1	10 ± 2
2-71	6.4 ± 1.9	5.4 ± 1.1	10.9 ± 2.4	8.0 ± 0.7
	6.1 ± 2.4			
2-81	2.7 ± 1.1	2.2 ± 1.1	-0.2 ± 1.5	1.9 ± 0.4
2-86	16 ± 2	0.13 ± 0.02	13.5 ± 2.3	Dry
2-87	NC	9.6 ± 2.6	8.9 ± 2.4	11.0 ± 1.0
		PS		
3-74	0.39 ± 0.72	1.5 ± 0.8	2.0 ± 1.3	2.3 ± 0.4
			PS	
3-82	0.46 ± 0.70	0.0 ± 0.5	0.1 ± 1.3	0.00 ± 0.09
3-86	6.5 ± 1.9	6.8 ± 1.5	6.8 ± 1.7	4.5 ± 0.5
3-87	NC	PS	0.0 ± 1.1	1.6 ± 0.2
		11 ± 2		
4-60	12 ± 3	0.24 ± 0.04	16.4 ± 3.3	24 ± 2
4-81	PS	Dry	PS	Dry
4-86	Dry	Dry	PS	Dry
4-87	22 ± 3	Dry	26.8 ± 3.2	16 ± 3
5-82	0.0 ± 0.53	0.0 ± 0.6	0.0 ± 1.2	0.00 ± 0.09
5-86	0.8 ± 0.9	PS	PS	Dry
5-87	NC	0.14 ± 0.03	9.4 ± 2.0	12 ± 1
6-81	PS	5.0 ± 1.1	3.4 ± 1.4	PS
6-82	4.6 ± 1.2	8.9 ± 1.4	0.1 ± 1.1	0.03 ± 0.08
6-86	PS	PS	PS	Dry
6-87	NC	NC	29.3 ± 3.9	PS
			PS	
7-74	0.88 ± 0.83	1.4 ± 0.8	1.5 ± 1.3	2.0 ± 0.4
			PS	
7-81	PS	PS	PS	PS
7-82	Dry	Dry	Dry	PS
7-86	Dry	Dry	PS	Dry
8-81	3.7 ± 1.0	3.2 ± 1.0	4.4 ± 1.6	PS
8-86	0.00 ± 0.45	0.18 ± 0.61	PS	0.98 ± 0.21
8-87	NC	4.2 ± 1.6	-0.2 ± 1.0	PS
9-74	6.0 ± 1.3	8.4 ± 1.4	12.0 ± 2.1	9.2 ± 0.9
	6.3 ± 2.3			PS
9-81	0.00 ± 0.47	0.00 ± 0.55	-0.1 ± 1.1	0.0 ± 0.7
9-86	1.8 ± 1.4	2.2 ± 1.0	1.9 ± 1.5	3.0 ± 0.5
9-87	NC	NC	NC	0.61 ± 0.19
10-74	Dry	8.2 ± 1.9	PS	PS
10-81	0.04 ± 0.56	0.00 ± 0.57	0.0 ± 1.0	0.05 ± 0.10
10-86	1.1 ± 1.5	0.22 ± 0.61	0.4 ± 1.3	0.11 ± 0.09
10-87	NC	NC	Dry	Dry
11-86	5.8 ± 2.0	6.0 ± 1.7	-0.2 ± 1.5	Dry
11-87	NC	NC	9.50 ± 0.98	NA
			PS	
12-86	25 ± 5	11 ± 3	17.4 ± 3.6	Dry
12-87	NC	NC	NC	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 19. 1987 Groundwater Quarterly Sampling Program Uranium-233, -234 (X 10^{-9} μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13-86	PS	PS	PS	Dry
14-86	2.6 ± 1.9	13 ± 2	1.6 ± 1.5	NA
	PS			
14-87	NC	NC	NC	0.00 ± 0.07
15-86	24 ± 4	1.7 ± 0.9	16.1 ± 2.4	NA
15-87	NC	NC	NC	0.97 ± 0.21
				PS
16-74	Dry	Dry	PS	Dry
16-86	1.0 ± 0.8	0.56 ± 0.69	2.3 ± 1.8	0.63 ± 0.33
16-87	NC	NC	NC	3.7 ± 0.5
17-86	26 ± 5	3.7 ± 1.2	24.8 ± 4.4	23 ± 3
17-87	NC	NC	NC	NA
18-86	Dry	Dry	PS	Dry
18-87	NC	NC	NC	NA
19-86	2.4 ± 1.3	0.96 ± 0.72	PS	5.5 ± 0.6
		4.1 ± 1.4	5.4 ± 1.6	
19-87	NC	NC	NC	NA
20-86	Dry	Dry	PS	Dry
20-87	NC	NC	NC	PS
21-86	4.8 ± 1.5	1.8 ± 0.9	2.4 ± 1.6	1.2 ± 0.3
21-87	NC	NC	NC	NA
22-74	3.5 ± 0.9	0.79 ± 0.94	5.3 ± 1.7	3.6 ± 0.4
22-86	9.2 ± 2.4	9.1 ± 1.8	5.8 ± 1.9	5.6 ± 0.5
22-87	NC	NC	NC	NA
23-86	NA	PS	PS	2.7 ± 0.4
23-87	NC	NC	NC	NA
24-86	Dry	Dry	PS	Dry
24-87	NC	NC	NC	NA
25-86	9.1 ± 2.6	2.3 ± 0.9	1.4 ± 1.7	6.6 ± 1.1
25-87	NC	NC	NC	NA
26-86	32 ± 6	Dry	34.2 ± 4.8	Dry
26-87	NC	NC	NC	NA
27-86	1.1 ± 0.9	1.7 ± 0.9	NA	NA
	1.8 ± 1.7			
27-87	NC	NC	NC	NA
28-86	211 ± 25	1000 ± 300	PS	Dry
28-87	NC	NC	NC	NA
29-86	Dry	Dry	PS	Dry
29-87	NC	NC	NC	NA
30-86	370 ± 250	150 ± 50	139.6 ± 21.1	160 ± 34
	19 ± 42			
30-87	NC	NC	NC	0.34 ± 0.12
31-86	Dry	Dry	PS	Dry
31-87	NC	NC	NC	NA
32-86	2.4 ± 1.1	0.57 ± 0.73	0.6 ± 1.3	0.89 ± 0.21
	1.3 ± 0.8			
32-87	NC	NC	NC	NA
33-86	Dry	Dry	PS	Dry
33-87	NC	NC	NC	NA
34-86	0.00 ± 0.45	0.39 ± 0.85	1.4 ± 1.3	0.66 ± 0.23
	1.7 ± 2.2			
34-87	NC	NC	NC	NA
35-86	5.2 ± 2.4	6.0 ± 1.9	4.8 ± 1.7	3.0 ± 0.5
35-87	NC	NC	NC	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 19. 1987 Groundwater Quarterly Sampling Program Uranium-233, -234 ($\times 10^{-9}$ μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
36-86	PS	PS	PS	Dry
36-87	NC	NC	NC	NA
				PS
37-86	Dry	Dry	PS	Dry
37-87	NC	NC	NC	NA
38-86	90 ± 11	60 ± 6	PS	Dry
38-87	NC	NC	NC	NA
39-86	3.2 ± 2.4	1.8 ± 0.8	2.8 ± 1.3	2.1 ± 0.4
			PS	
39-87	NC	NC	NC	NA
40-86	10 ± 2	PS	NC	6.7 ± 0.8
40-87	NC	NC	PS	Dry
41-86	3.7 ± 1.2	2.0 ± 0.9	1.6 ± 1.2	3.0 ± 0.4
41-87	NC	NC	NA	NA
			PS	
42-86	2.7 ± 1.2	1.4 ± 0.8	2.8 ± 1.4	1.9 ± 0.3
42-87	NC	PS	PS	Dry
43-86	2.6 ± 1.1	1.7 ± 0.8	1.2 ± 1.2	NA
			PS	
43-87	NC	NC	NC	20 ± 4
44-86	0.76 ± 0.85	8.5 ± 7.5	2.0 ± 1.5	1.9 ± 0.3
44-87	NC	NC	NC	NA
45-86	1.5 ± 1.1	0.00 ± 0.59	2.0 ± 1.5	*0.00 ± 0.06*
45-87	NC	NC	NC	2.7 ± 0.4
46-86	5.7 ± 1.2	4.0 ± 1.4	3.9 ± 1.6	4.244 ± 0.669
				2.6 ± 0.4
47-86	0.00 ± 0.53	0.00 ± 0.59	0.4 ± 1.4	0.15 ± 0.09
47-87	NC	NC	NC	PS
48-86	4.4 ± 5.1	1.8 ± 0.8	0.8 ± 1.5	0.77 ± 0.17
48-87	NC	NC	NC	PS
49-86	0.00 ± 0.91	3.5 ± 0.9	0.9 ± 1.4	0.13 ± 0.09
49-87	NC	NC	NC	NA
50-86	2.5 ± 1.2	0.08 ± 0.65	NA	0.23 ± 0.12
50-87	NC	NC	NC	PS
51-86	0.22 ± 0.61	0.00 ± 0.06	-0.4 ± 1.1	0.10 ± 0.10
				PS
51-87	NC	NC	NC	NA
52-86	0.09 ± 0.64	0.0 ± 0.5	0.0 ± 1.1	0.04 ± 0.07
52-87	NC	NC	NC	21 ± 2
				PS
53-86	Dry	Dry	PS	PS
53-87	NC	NC	NC	PS
54-86	0.19 ± 0.06	0.4 ± 1.0	2.4 ± 1.3	1.4 ± 0.3
			PS	
54-87	NC	NC	NC	PS
55-86	1.5 ± 0.9	0.31 ± 0.67	0.3 ± 1.1	0.00 ± 0.06
			PS	
55-87	NC	NC	NC	PS
56-86	0.34 ± 0.69	0.00 ± 0.85	0.8 ± 1.1	0.04 ± 0.13
56-87	NC	NC	NC	Dry
57-86	8.7 ± 1.9	Dry	PS	PS
	PS			
58-86	Dry	Dry	PS	PS
58-87	NC	NC	NC	NA
59-86	15 ± 2	15 ± 2	13.1 ± 2.2	10 ± 1
	11.00 ± 0.03			

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 19. 1987 Groundwater Quarterly Sampling Program Uranium-233, -234 ($\times 10^{-9}$ μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
60-87	NC	NC	NC	NA
61-86	3.7 ± 1.3	2.5 ± 1.0	3.6 ± 1.4	PS
	3.3 ± 1.3			
61-87	NC	NC	NC	NA
62-86	0.6 ± 1.6	3.4 ± 1.2	4.3 ± 1.4	4.0 ± 0.5
	4.9 ± 1.3			
62-87	NC	NC	NC	NA
63-86	Dry	Dry	PS	PS
63-87	NC	NC	NC	NA
64-86	1.7 ± 1.0	PS	NA	PS
64-87	NC	NC	NC	NA
65-86	3.6 ± 1.1	4.0 ± 1.1	PS	PS
			4.2 ± 1.9	
65-87	NC	NC	NC	NA
66-86	0.00 ± 0.54	0.40 ± 0.71	PS	Dry
66-87	NC	NC	NC	NA
67-86	3.5 ± 1.2	3.4 ± 1.1	1.6 ± 1.3	Dry
67-87	NC			
68-86	4.2 ± 2.1	0.12 ± 0.66	0.0 ± 1.0	Dry
68-87	NC	NC	NC	NA
69-86	12 ± 3	10 ± 2	9.1 ± 1.9	8.4 ± 0.9
70-86	0.00 ± 0.58	0.45 ± 0.83	0.4 ± 1.0	0.29 ± 0.17
70-87	NC	NC	NC	NA
71-87	NC	NC	NC	NA
72-87	NC	NC	NC	NA
WS-01	NA	NA	1.1 ± 1.4	0.00 ± 0.10
WS-02	NA	0.00 ± 0.57	10.4 ± 2.4	NA
		2.4 ± 0.9		

1987 Summary

Minimum Value: -0.4 ± 1.1 (Well 51-86 Quarter 3)

Maximum Value: 1000 ± 300 (Well 28-86 Quarter 2)

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 20. 1987 Groundwater Quarterly Sampling Program Uranium-238 ($\times 10^{-9}$ μCi/mℓ)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1-71	3.3 ± 0.8	2.8 ± 0.8	4.1 ± 1.1	1.7 ± 0.3
	1.9 ± 1.1			
1-74	1.6 ± 1.1	1.8 ± 0.8	2.5 ± 0.8	2.0 ± 0.8
1-81	2.2 ± 2.0	1.6 ± 0.7	0.5 ± 1.1	0.81 ± 0.17
1-86	2.3 ± 1.1	0.90 ± 0.56	-0.2 ± 0.5	PS
1-87	NC	Dry	Dry	Dry
2-60	17 ± 4	PS	15.7 ± 7.9	6.6 ± 1.1
2-71	4.7 ± 1.6	3.4 ± 0.8	7.9 ± 1.8	5.2 ± 0.5
	1.6 ± 1.9			
2-81	2.6 ± 1.0	1.5 ± 0.8	1.0 ± 1.3	1.0 ± 0.2
2-86	13 ± 2	0.11 ± 0.02	13.4 ± 2.1	Dry
2-87	NC	6.3 ± 1.9	3.7 ± 1.4	4.5 ± 0.5
		PS		
3-74	0.68 ± 0.59	1.8 ± 0.7	1.8 ± 0.8	1.4 ± 0.3
			PS	
3-82	0.33 ± 0.54	0.3 ± 0.4	1.5 ± 1.3	0.04 ± 0.10
3-86	3.9 ± 1.6	4.9 ± 1.2	5.3 ± 1.3	3.8 ± 0.5
3-87	NC	PS	0.3 ± 0.7	0.53 ± 0.13
		11 ± 2		
4-60	6.2 ± 1.8	0.12 ± 0.03	10.1 ± 2.4	8.4 ± 0.8
4-81	PS	Dry	PS	Dry
4-86	Dry	Dry	PS	Dry
4-87	14 ± 3	Dry	17.4 ± 2.3	12 ± 2
5-82	0.00 ± 0.41	0.09 ± 0.41	-0.3 ± 1.0	0.00 ± 0.07
5-86	0.49 ± 0.06	NA	NA	Dry
5-87	NC	9.1 ± 2.2	5.9 ± 1.5	8.0 ± 0.8
6-81	PS	4.8 ± 1.0	4.0 ± 1.1	PS
6-82	9.7 ± 1.7	7.4 ± 1.2	-0.2 ± 0.6	0.14 ± 0.10
6-86	PS	PS	PS	Dry
6-87	NC	NC	25.3 ± 3.4	PS
			PS	
7-74	0.84 ± 0.66	0.3 ± 0.5	1.3 ± 0.9	1.3 ± 0.3
			PS	
7-81	PS	PS	PS	PS
7-82	Dry	Dry	Dry	PS
7-86	Dry	Dry	PS	Dry
8-81	3.3 ± 0.8	4.5 ± 1.0	4.6 ± 1.4	PS
8-86	0.00 ± 0.75	2.3 ± 5.4	PS	0.45 ± 0.14
8-87	NC	4.7 ± 1.5	-0.3 ± 0.5	PS
9-74	5.0 ± 1.1	7.7 ± 1.3	8.1 ± 1.5	7.00 ± 0.07
	2.9 ± 2.1			PS
9-81	0.00 ± 0.25	0.09 ± 0.42	0.1 ± 0.7	0.08 ± 0.11
9-86	0.28 ± 0.97	0.3 ± 0.5	5.3 ± 2.0	0.98 ± 0.28
9-87	NC	NC	NC	0.38 ± 0.14
				PS
10-74	Dry	4.2 ± 1.3	PS	PS
10-81	0.12 ± 0.40	0.17 ± 0.42	-0.3 ± 0.6	0.20 ± 0.12
10-86	4.3 ± 1.9	0.05 ± 0.38	4.5 ± 1.5	NA
10-87	NC	NC	Dry	Dry
11-86	5.2 ± 1.8	6.8 ± 1.8	-0.3 ± 1.2	Dry
11-87	NC	NC	6.5 ± 0.7	NA
12-86	20 ± 5	13 ± 3	15.1 ± 3.3	Dry
12-87	NC	NC	NA	NA
13-86	PS	PS	PS	Dry

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 20. 1987 Groundwater Quarterly Sampling Program Uranium-238 ($\times 10^{-9}$ μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
14-86	0.2 ± 1.0	14 ± 2	-0.9 ± 1.0	0.22 ± 0.12
	PS			
14-87	NC	NC	NC	0.00 ± 0.06
15-86	19 ± 3	0.43 ± 0.54	11.0 ± 1.9	NA
15-87	NC	NC	NC	0.73 ± 0.18
16-74	Dry	Dry	PS	Dry
16-86	0.48 ± 0.53	1.1 ± 0.6	-0.4 ± 1.2	0.14 ± 0.18
16-87	NC	NC	NC	2.20 ± 0.34
17-86	25 ± 4	2.7 ± 0.8	20.9 ± 4.0	21 ± 3
17-87	NC	NC	NC	NA
18-86	Dry	Dry	PS	Dry
19-86	3.2 ± 1.4	0.34 ± 0.09	PS	7.9 ± 0.9
		4.0 ± 1.3	4.5 ± 1.4	
19-87	NC	NC	NC	NA
20-86	Dry	Dry	PS	Dry
20-87	NC	NC	NC	PS
21-86	5.4 ± 1.5	1.6 ± 0.7	0.6 ± 1.2	0.89 ± 0.22
21-87	NC	NC	NC	NA
22-74	1.6 ± 0.6	3.1 ± 1.2	1.7 ± 0.9	1.4 ± 0.3
22-86	4.3 ± 1.9	6.0 ± 1.4	7.5 ± 2.0	2.2 ± 0.3
22-87	NC	NC	NA	NA
23-86	NA	PS	PS	1.1 ± 0.2
23-87	NC	NC	NA	NA
24-86	Dry	Dry	PS	Dry
24-87	NC	NC	NA	NA
25-86	7.0 ± 1.9	1.8 ± 0.8	2.4 ± 1.7	2.1 ± 0.5
25-87	NC	NC	NA	NA
26-86	3.0 ± 5.1	Dry	31.2 ± 1.0	Dry
26-87	NC	NC	NA	NA
27-86	0.39 ± 0.59	0.97 ± 0.61	NA	0.45 ± 0.14
	2.6 ± 1.7			
27-87	NC	NC	NA	NA
28-86	142 ± 20	750 ± 200	PS	Dry
28-87	NC	NC	NA	NA
29-86	Dry	Dry	PS	Dry
29-87	NC	NC	NC	NA
30-86	32 ± 57	97 ± 34	93.1 ± 14.7	100 ± 22
	125 ± 29			
30-87	NC	NC	NA	0.11 ± 0.09
31-86	Dry	Dry	PS	Dry
31-87	NC	NC	NC	NA
32-86	0.87 ± 0.87	0.52 ± 0.54	3.2 ± 1.0	0.32 ± 0.13
	1.6 ± 0.8			
32-87	NC	NC	NC	NA
33-86	Dry	Dry	PS	Dry
33-87	NC	NC	NA	NA
34-86	0.5 ± 1.1	0.04 ± 0.53	0.4 ± 0.7	1.2 ± 0.3
	0.0 ± 2.2			
34-87	NC	NC	NA	NA
35-86	1.3 ± 3.5	1.4 ± 1.0	3.2 ± 1.3	1.7 ± 0.3
			PS	
35-87	NC	NC	NA	NA
36-86	PS	PS	PS	Dry
36-87	NC	NC	NA	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 20. 1987 Groundwater Quarter Sampling Program Uranium-238 ($\times 10^{-9}$ μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
37-86	Dry	Dry	PS	Dry
37-87	NC	NC	NC	NA
38-86	75 ± 9	46 ± 5	NA	Dry
38-87	NC	NC	NC	NA
39-86	2.3 ± 2.2	1.4 ± 0.6	1.8 ± 0.8	1.7 ± 0.3
			PS	
39-87	NC	NC	NC	NA
40-86	6.1 ± 1.5	PS	PS	3.6 ± 0.5
40-87	NC	NC	PS	Dry
41-86	5.2 ± 1.3	0.93 ± 0.65	1.2 ± 0.7	1.7 ± 0.3
				NA
41-87	NC	NC	NA	NA
42-86	2.2 ± 1.1	1.6 ± 0.6	2.6 ± 1.0	1.4 ± 0.2
42-87	NC	PS	PS	Dry
43-86	3.9 ± 1.1	1.0 ± 0.5	1.7 ± 0.9	17 ± 4
			PS	
43-87	NC	NC	NC	NA
44-86	2.2 ± 1.0	2.3 ± 0.8	2.5 ± 1.3	3.4 ± 0.4
44-87	NC	NC	NA	NA
45-86	1.0 ± 0.9	0.00 ± 0.35	9.8 ± 2.3	0.20 ± 0.96
45-87	NC	NC	NC	1.4 ± 0.2
46-86	3.9 ± 1.0	2.3 ± 1.0	7.5 ± 1.7	2.3 ± 0.33
				1.2 ± 0.2
47-86	0.00 ± 0.38	0.36 ± 0.48	5.5 ± 2.1	0.18 ± 0.08
47-87	NC	NC	NC	NA
48-86	1.1 ± 5.0	1.2 ± 0.6	0.0 ± 1.5	0.42 ± 0.13
48-87	NC	NC	NC	PS
49-86	0.7 ± 3.6	4.0 ± 0.9	0.0 ± 1.0	0.01 ± 0.06
49-87	NC	NC	NC	NA
50-86	3.5 ± 1.2	0.20 ± 0.44	NA	0.18 ± 0.10
50-87	NC	NC	NC	PS
51-86	0.61 ± 0.54	0.12 ± 0.37	0.0 ± 0.5	0.07 ± 0.08
		0.12 ± 0.37		PS
51-87	NC	NC	NC	NA
52-86	0.31 ± 0.46	0.2 ± 0.4	0.0 ± 0.7	0.05 ± 0.05
52-87	NC	NC	NC	15 ± 2
				PS
53-86	Dry	Dry	PS	PS
53-87	NC	NC	NC	PS
54-86	0.14 ± 0.03	0.07 ± 0.87	0.3 ± 0.6	0.44 ± 0.12
			PS	
54-87	NC	NC	NC	PS
55-86	2.2 ± 0.8	0.45 ± 0.48	0.0 ± 0.5	0.02 ± 0.05
55-87	NC	NC	NA	NA
56-86	0.86 ± 0.60	0.00 ± 0.71	0.4 ± 0.6	0.11 ± 0.09
56-87	NC	NC	NC	NA
57-86	5.3 ± 1.5	Dry	PS	PS
58-86	Dry	Dry	PS	PS
58-87	NC	NC	NC	NA
59-86	11 ± 2	10 ± 2	10.9 ± 1.7	8.1 ± 0.9
	5.3 ± 2.9			
59-87	NC	NC	NC	NA
60-87	NC	NC	NC	NA
61-86	2.3 ± 0.9	2.0 ± 0.9	1.6 ± 0.8	PS
	1.8 ± 0.9			
61-87	NC	NC	NC	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 20. 1987 Groundwater Quarterly Sampling Program Uranium-238 ($\times 10^{-9}$ μCi/mℓ) (Continued).

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
62-86	1.8 ± 1.6 3.6 ± 1.1	2.8 ± 1.0	3.2 ± 1.0	3.0 ± 0.4
62-87	NC	NC	NC	NA
63-86	Dry	Dry	PS	PS
63-87	NC	NC	NC	NA
64-86	2.1 ± 1.0	PS	NA	PS
64-87	NC	NC	NC	NA
65-86	1.9 ± 0.7	3.3 ± 1.0	PS 1.6 ± 1.5	PS
65-87	NC	NC	NC	NA
66-86	1.1 ± 0.7	0.94 ± 0.6	PS	Dry
66-87	NC	NC	NC	NA
67-86	2.7 ± 1.0	1.7 ± 0.8	2.5 ± 1.0	Dry
67-87	NC	NC	NC	NA
68-86	5.2 ± 2.2	0.34 ± 0.48	0.9 ± 0.7	Dry
68-87	NC	NC	NC	NA
69-86	33 ± 5	7.2 ± 1.3	8.9 ± 1.6	6.5 ± 0.7
70-86	0.72 ± 0.60	0.87 ± 0.73	0.4 ± 0.6	0.35 ± 0.15
70-87	NC	NC	NC	NA
71-87	NC	NC	NC	NA
72-87	NC	NC	NC	NA
WS-01	NA	NA	7.1 ± 2.0	0.03 ± 0.09
WS-02	NA	0.7 ± 0.5 2.6 ± 0.9	12.6 ± 2.6	PS

1987 Summary

Minimum Value: −0.9 ± 1.0 (Well 14-86 Quarter 3)

Maximum Value: 750 ± 200 (Well 28-86 Quarter 2)

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 21. 1987 Groundwater Quarterly Sampling Program Tritium ($\times 10^{-9}$ μCi/mℓ)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1-71	<110	<110	<515	<460
	290			
1-74	260	<110	<475	<460
1-81	320	260	<478	<220
1-86	<110	<110	<492	PS
1-87	NC	Dry	Dry	Dry
2-60	<110	PS	1027 ± 317	870 ± 100
2-71	<110	<110	<515	<460
	170			
2-81	<110	<110	<478	<220
2-86	<110	<110	<475	Dry
2-87	NC	120	<514	<500
3-74	230	<110	<475	<520
3-82	<110	<110	557 ± 323	<210
3-86	260	320	<502	<220
3-87	NC	PS	<514	<500
		<110		
4-60	1700	2600	3000 ± 420	1600 ± 100
4-81	PS	Dry	PS	Dry
4-86	Dry	Dry	PS	Dry
4-87	<110	Dry	777 ± 333	<460
4-82	120	<110	1005 ± 316	<200
5-86	120	PS	<540	Dry
5-87	NC	<110	<493	<460
6-81	PS	1110	<471	PS
6-82	<110	<110	<459	<200
6-86	PS	PS	PS	Dry
6-87	NC	NC	<540	PS
			PS	
7-74	<110	<110	<475	<460
			PS	
7-81	PS	PS	PS	PS
7-82	Dry	Dry	Dry	Dry
7-86	Dry	Dry	PS	Dry
8-81	<110	<110	<535	<220
8-86	<110	<110	PS	<210
8-87	NC	<110	<514	PS
9-74	<110	<110	<515	<520
				PS
9-81	<110	<110	<535	<220
9-86	<110	<110	<492	<220
9-87	NC	NC	NA	510 ± 290
10-74	Dry	<110	Dry	PS
10-81	<110	<110	<526	<220
10-86	<110	<110	<540	<220
10-87	NC	NC	Dry	Dry
11-86	460	160	<490	Dry
			PS	
11-87	NC	NC	<440	Dry
			PS	
12-86	130	120	<540	Dry
			PS	
12-87	NC	NC	PS	PS
13-86	PS	PS	PS	Dry

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 21. 1987 Groundwater Quarterly Sampling Program Tritium ($\times 10^{-9}$ μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
14-86	<110	<110	<492	<210
	PS			
14-87	NC	NC	<500	<460
15-86	<110	<110	<492	<210
15-87	NC	NC	<460	<500
				PS
16-74	Dry	Dry	PS	Dry
16-86	<110	<110	<540	<210
16-87	NC	NC	<500	<460
17-86	380	<110	<540	730 ± 100
17-87	NC	NC	PS	NA
18-86	Dry	Dry	PS	Dry
18-87	NC	NC	NA	NA
19-86	110	<110	PS	<210
		<110	<445	
19-87	NC	NC	NA	NA
20-86	Dry	Dry	PS	Dry
20-87	NC	NC	NC	PS
21-86	110	<110	<445	<200
21-87	NC	NC	NC	NA
22-74	<110	<110	<478	<520
22-86	230	<110	723 ± 318	260 ± 80
22-87	NC	NC	PS	<220
23-86	PS	PS	PS	PS
23-87	NC	NC	<460	<520
24-86	Dry	Dry	PS	Dry
24-87	NC	NC	NA	NA
25-86	210	<110	<492	<220
25-87	NC	NC	<460	<520
26-86	1300	Dry	1352 ± 343	Dry
26-87	NC	NC	NA	NA
27-86	<110	<110	NA	NA
	<110			
27-87	NC	NC	NA	NA
28-86	6300	12000	PS	Dry
28-87	NC	NC	NA	NA
29-86	Dry	Dry	PS	Dry
29-87	NC	NC	Dry	<460
30-86	85000	9800	8611 ± 825	7900 ±200
	6400			
30-87	NC	NC	NA	NA
31-86	Dry	Dry	PS	Dry
31-87	NC	NC	NC	<460
32-86	<110	<110	<472	NA
	<110			
32-87	NC	NC	NC	<460
33-86	Dry	Dry	PS	Dry
33-87	NC	NC	Dry	NA
34-86	<110	<110	<478	NA
	<110			
34-87	NC	NC	Dry	Dry
35-86	<110	<110	<478	<460
35-87	NC	NC	<478	<460
36-86	PS	PS	PS	Dry
36-87	NC	NC	PS	PS
			PS	

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 21. 1987 Groundwater Quarterly Sampling Program Tritium ($\times 10^{-9}$ μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
37-86	Dry	Dry	PS	Dry
37-87	NC	NC	NC	NA
38-86	150	160	<540	Dry
38-87	NC	NC	NA	NA
39-86	250	<110	PS <502	<210
39-87	NC	NC	NC	NA
40-86	110	PS	PS	NA
40-87	NC	NC	PS	Dry
41-86	220	<110	<475	NA <520
41-87	NC	NC	NA PS	NA <210
42-86	<110	<110	<502	560 ± 290
42-87	NC	PS	PS	Dry
43-86	<110	<110	<493	Dry
43-87	NC	NC	NC	<220
44-86	<110	<110	<526	<210
44-87	NC	NC	NC	Dry
45-86	110	330	<535	<460
45-87	NC	NC	NC	<220
46-86	110	<110	<526	NA <460
47-86	110	<110	<526	<460
47-87	NC	NC	NC	PS
48-86	310	<110	<526	NA
48-87	NC	NC	NC	PS
49-86	<110	<110	2218 ± 397	<220 PS
49-87	NC	NC	NC	NA
50-86	160	NA	487 ± 291	<220
50-87	NC	NC	NC	PS
51-86	150	NA	<492	<220
52-86	150	<110	<459	<500
52-87	NC	NC	NC	<540 PS
53-86	Dry	Dry	PS	PS
53-87	NC	NC	NC	PS
54-86	230	<110	<593 PS	Dry
54-87	NC	NC	NC	PS
55-86	260	260	<593 PS	PS
55-87	NC	NC	NC	PS
56-86	120	<110	<493	Dry
56-87	NC	NC	NC	Dry
57-86	NA	Dry	PS	PS
58-86	Dry	Dry	PS	PS
58-87	NC	NC	NC	NA
59-86	<110 450	210	<493	<460
59-87	NC	NC	NC	NA
60-87	NC	NC	NC	NA
61-86	<110 200	NA	<509	PS

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 21. 1987 Groundwater Quarterly Sampling Program Tritium ($\times 10^{-9}$ μCi/mℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
62-86	<110	<110	<493	<520
62-87	NC	NC	NC	NA
63-86	Dry	Dry	PS	PS
63-87	NC	NC	NC	NA
64-86	<110	PS	NA	PS
64-87	NC	NC	NC	NA
65-86	<110	<110	PS <509	PS
65-87	NC	NC	NC	NA
66-86	<110	<110	PS	Dry
66-87	NC	NC	NC	NA
67-86	270	420	<475	Dry
67-87	NC	NC	NC	NA
68-86	110	<110	<493	Dry
68-87	NC	NC	NC	NA
69-86	300	<110	<493	510 ± 290
70-86	<110	<110	<493	<220
70-87	NC	NC	NC	NA
71-87	NC	NC	NC	NA
72-87	NC	NC	NC	NA
WS-01	120	<110	<492	<210
WS-02	260	<110 <110	<492	NA

1987 Summary

Minimum Value: <515 (Well 1-71 Quarter 3)

Maximum Value: 85000 (Well 30-86 Quarter 1)

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.

TABLE 22. 1987 Groundwater Quarterly Sampling Program Trichloroethylene (μg/ℓ)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1-71	1120	2000	691	222
	1200			
1-74	8000	18000	114	1340
1-81	4 U	4 U	4 U	5 U
				NA
1-86	4 U	4 U	4 U	PS
1-87	NC	Dry	Dry	Dry
2-60	4 U	4 U	5 U	5 U
2-71	28800	24800	9440	NA
	26000			
2-81	4 U	4 U	NA	5 U
2-86	4 U	4 U	4 U	Dry
2-87	NC	PS		
		5 U		
3-74	200	400	218	55
3-82	4 U	4 U	5 U	NA
3-86	4 U	4 U	4 U	5 U
3-87	NC	5 U	4 U	5 U
4-60	4 U	4 U	5 U	5 U
4-81	4 U	Dry	4 U	Dry
4-86	Dry	Dry	PS	Dry
4-87	525	Dry	23	44
5-82	4 U	4 U	5 U	5 U
5-86	4 U	4 U	NA	Dry
5-87	NC	4 U	4 U	5 U
6-81	4 U	4 U	5 U	5 U
6-82	4 U	4 U	5 U	5 U
6-86	4 U	4 U	5 U	Dry
6-87	NC	NC	PS	12
			20	
7-74	4 U	4 U	PS	5 U
			16	
7-81	4 U	4 U	5 U	5 U
7-82	Dry	Dry	Dry	PS
7-86	Dry	Dry	PS	Dry
8-81	4 U	4 U	5 U	PS
8-86	4 U	4 U	5 U	5 U
8-87	NC	4 U	4 U	5 U
9-74	20000	72000	11768	12760
	20800			17538
9-81	4 U	4 U	5 U	NA
9-86	4 U	4 U	5 U	NA
9-87	NC	NC	NC	5 U
				5 U
10-74	Dry	3600	PS	258
10-81	4 U	4 U	5 U	NA
10-86	4 U	4 U	5 U	5 U
11-86	4 U	4 U	NA	Dry
11-87	NC	NC	595	NA
			590	NA
			PS	NA
12-86	4 U	4 U	5 U	Dry
12-87	NC	NC	3570	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - Undetected. The number preceding the "U" is the detection limit of the analytical instrument.

TABLE 22. 1987 Groundwater Quarterly Sampling Program Trichloroethylene (μg/ℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13-86	4 U	4 U	5 U	Dry
			PS	
14-86	4 U	4 U	5 U	5 U
	4 U			
14-87	NC	NC	109	47
15-86	4 U	4 U	5 U	5 U
15-87	NC	NC	510	PS
16-74	Dry	Dry	PS	Dry
16-86	4 U	4 U	5 U	5 U
16-87	Dry	Dry	5 U	5 U
17-86	4 U	4 U	5 U	5 U
17-87	Dry	Dry	Dry	83
18-86	Dry	Dry	PS	Dry
18-87	NC	NC	NC	NA
19-86	4 U	4 U	PS	8
		4 U	5 U	
19-87	NC	4 U	5 U	NA
20-86	Dry	Dry	PS	Dry
20-87	NC	NC	NC	NA
21-86	4 U	4 U	5 U	5 U
21-87	NC	NC	NC	NA
22-74	32	PS	NA	8
22-86	650	6000	490	186
22-87	NC	NC	NC	NA
23-86	4 U	4 U	5 U	PS
23-87	NC	NC	5 U	5 U
24-86	Dry	Dry	PS	Dry
24-87	NC	NC	NC	5 U
25-86	4 U	4 U	5 U	NA
25-87	NC	NC	56	42
26-86	8	Dry	5 U	Dry
26-87	NC	NC	NC	5 U
27-86	4 U	4 U	5 U	5 U
	4 U			
27-87	NC	NC	NC	NA
28-86	4 U	4 U	5 U	Dry
28-87	NC	NC	NA	NA
29-86	Dry	Dry	NA	NA
29-87	NC	NC	NC	5 U
30-86	5	4 U	5 U	NA
	4 U			
30-87	NC	NC	NC	NA
31-86	Dry	Dry	PS	Dry
31-87	NC	NC	NC	5 U
32-86	4 U	4 U	5 U	5 U
	4 U			
32-87	NC	NC	NC	27
33-86	Dry	Dry	PS	Dry
33-87	NC	NC	NC	NA
34-86	4 U	4 U	PS	5 U
34-87	NC	NC	NC	NA
35-86	14	16	PS	5U
35-87	NC	NC	NC	NA
36-86	6	4 U	PS	Dry
36-87	NC	NC	NC	118298

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - *Undetected. The number preceding* the "U" is the detection limit of the analytical instrument.

TABLE 22. 1987 Groundwater Quarterly Sampling Program Trichloroethylene (μg/ℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
37-86	Dry	Dry	Dry	Dry
37-87	NC	NC	NA	NA
38-86	4 U	4 U	NC	Dry
38-87	NC	NC	NC	NA
39-86	4 U	4 U	5 U	5 U
39-87	NC	NC	NC	NA
40-86	4 U	4 U	PS	5 U
			PS	
40-87	NC	NC	PS	Dry
41-86	4 U	4 U	4 U	NA
				5 U
41-87	NC	NC	5 U	NA
			5 U	5 U
42-86	110	1400	PS	197
			870	5 U
42-87	NC	5	PS	Dry
43-86	8	4 U	5 U	6999
43-87	NC	NC	5 U	NA
44-86	4 U	4 U	5 U	5 U
44-87	NC	NC	NC	NA
45-86	4 U	4 U	5 U	5 U
45-87	NC	NC	NC	5 U
46-86	4 U	4 U	5 U	5 U
47-86	4 U	4 U	5 U	5 U
				5U
47-87	NC	NC	NC	5 U
48-86	4 U	4 U	5 U	5 U
48-87	NC	NC	NC	5 U
49-86	4 U	4 U	5 U	5 U
49-87	NC	NC	NC	NA
50-86	4 U	4 U	5 U	5 U
50-87	NC	NC	NC	5 U
51-86	4 U	4 U	5 U	5 U
51-87	NC	NC	NC	NA
52-86	4 U	4 U	5 U	5 U
52-87	NC	NC	NC	5 U
53-86	Dry	Dry	PS	PS
53-87	NC	NC	NC	23
54-86	4 U	4 U	4 U	Dry
54-87	NC	NC	NC	5 U
55-86	4 U	4 U	4 U	5 U
55-87	NC	NC	5 U	NA
56-86	4 U	4 U	4 U	Dry
56-87	NC	NC	NC	Dry
57-86	4 U	Dry	PS	PS
58-86	Dry	Dry	Dry	Dry
58-87	NC	NC	NC	NA
59-86	4 U	4 U	4 U	5 U
59-87	NC	NC	NC	NA
60-87	NC	NC	NC	NA
61-86	4 U	4 U	5 U	PS
61-87	NC	NC	NC	NA
62-86	4 U	4 U	4 U	5 U
	4 U			

Dry - Well was dry.
NA - Data no available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
N - Undetected. The number preceding the "U" is the detection limit of the analytical instrument.

TABLE 22. 1987 Groundwater Quarterly Sampling Program Trichloroethylene (μg/ℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
62-87	NC	NC	NC	NA
63-86	Dry	Dry	PS	PS
63-87	NC	NC	NC	NA
64-86	4 U	4 U	4 U	PS
64-87	NC	NC	NC	NA
64-86	4 U	4 U	4 U	PS
65-87	NC	NC	NC	NA
66-86	4 U	4 U	PS	Dry
66-87	NC	NC	NC	NA
67-86	4 U	4 U	4 U	Dry
67-87	NC	NC	NC	NA
68-86	4 U	4 U	4 U	Dry
68-87	NC	NC	NC	NA
69-86	4 U	4 U	4 U	5 U
70-86	4 U	4 U	4 U	5 U
70-87	NC	NC	NC	NA
71-87	NC	NC	NC	NA
72-87	NC	NC	NC	NA
WS-01	1000	4 U	5 U	5 U
WS-02	4 U	4 U	5 U	5 U

1987 Summary

Minimum Value: Many locations below detection levels.

Maximum Value: 118298 (Well 36-87 Quarter 4)

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - Undetected. The number preceding the "U" is the detection limit of the analytical instrument.

TABLE 23. 1987 Groundwater Quarterly Sampling Program Carbon Tetrachloride ($\mu g/\ell$)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1-71	4800	3000	1405	440
	2300			
1-74	4 U	4 U	4 U	5 U
1-81	4 U	4 U	4 U	5 U
1-86	4 U	4 U	4 U	PS
		4 U		
1-87	NC	Dry	Dry	Dry
2-60	4 U	4 U	5 U	7
2-71	4 U	40	4 U	NA
	4 U			
2-81	4 U	4 U	PS	5 U
2-86	4 U	4 U	4 U	Dry
2-87	NC	5 U	4 U	5 U
3-74	1200	1200	1885	651
3-82	4 U	4 U	5 U	NA
3-86	4 U	4 U	4 U	5 U
3-87	NC	5 U	4 U	5 U
4-60	4 U	4 U	5 U	7
4-81	4 U	Dry	4 U	Dry
4-86	Dry	Dry	Dry	Dry
4-87	5	Dry	4 U	10
5-82	4 U	4 U	5 U	8
5-86	4 U	4 U	NA	Dry
5-87	NC	4 U	4 U	5 U
6-81	4 U	4 U	5 U	7
6-82	4 U	4 U	5 U	8
6-86	4 U	4 U	5 U	Dry
6-87	NC	NC	5 U	5 U
7-74	4 U	4 U	NA	10
			150	
7-81	4 U	4 U	5 U	7
7-82	Dry	Dry	Dry	NA
7-86	Dry	Dry	Dry	Dry
8-81	4 U	4 U	5 U	NA
8-86	4 U	4 U	5 U	5 U
8-87	NC	4 U	4 U	5 U
9-74	4 U	28000	4 U	3522
	4 U			
9-81	4 U	4 U	5 U	NA
9-86	4 U	4 U	5 U	NA
9-87	NC	NC	NC	5 U
10-74	Dry	1400	Dry	441
10-81	4 U	4 U	5 U	NA
10-86	4 U	4 U	5 U	5 U
11-86	4 U	4 U	Dry	Dry
11-87	NC	NC	560	NA
			430	NA
12-86	4 U	4 U	5 U	Dry
12-87	NC	NC	58	NA
13-86	4 U	4 U	5 U	Dry
14-86	4 U	4 U	5 U	5 U
	4 U			

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - Undetected. The number preceding the "U" is the detection limit of the analytical instrument.

TABLE 23. 1987 Groundwater Quarterly Sampling Program Carbon Tetrachloride (μg/ℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
14-87	NC	NC	404	258
15-86	4 U	4 U	5 U	5 U
15-87	NC	NC	4080	NA
16-74	Dry	Dry	Dry	Dry
16-86	4 U	4 U	5 U	5 U
16-87	NC	NC	5 U	5 U
17-86	4 U	4 U	5 U	5 U
17-87	NC	NC	NC	96
18-86	Dry	Dry	Dry	Dry
18-87	NC	NC	NC	NA
19-86	4 U	4 U	PS	5 U
		4 U	5 U	NA
19-87	NC	4 U	5 U	8
22-74	64	NA	NA	54
22-86	4 U	3000	491	161
22-87	NC	NC	NC	NA
23-86	4 U	4 U	5 U	PS
23-87	NC	NC	5 U	5 U
24-86	Dry	Dry	Dry	Dry
24-87	NC	NC	NC	5 U
25-86	4 U	4 U	5 U	NA
25-87	NC	NC	61	75
26-86	4 U	Dry	5 U	Dry
26-87	NC	NC	NC	5 U
27-86	4 U	4 U	5 U	5 U
27-87	NC	NC	NC	NA
28-86	4 U	4 U	5 U	Dry
28-87	NC	NC	NA	NA
29-86	Dry	Dry	NA	NA
29-87	NC	NC	NC	5 U
30-86	4 U	4 U	5 U	NA
30-87	NC	NC	NC	NA
31-86	Dry	Dry	Dry	Dry
31-87	NC	NC	NC	5 U
32-86	4 U	4 U	5 U	5 U
	4 U			
32-87	NC	NC	NC	5 U
33-86	Dry	Dry	Dry	Dry
33-87	NC	NC	NC	NA
34-86	4 U	4 U	NA	5 U
34-87	NC	NC	NC	NA
35-86	4 U	23	NA	5 U
35-87	NC	NC	5 U	NA
36-86	4 U	4 U	PS	Dry
			NA	
			5 U	
36-87	NC	NC	NC	3673
37-86	Dry	Dry	Dry	Dry
37-87	NC	NC	NC	NA
38-86	4 U	4 U	NA	Dry
38-87	NC	NC	NC	NA
39-86	4 U	4 U	5 U	5 U
39-87	NC	NC	NC	NA
40-86	4 U	4 U	PS	5 U
			PS	
40-87	NC	NC	PS	Dry

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - Undetected. The number preceding the "U" is the detection limit of the analytical instrument.

TABLE 23. 1987 Groundwater Quarterly Sampling Program Carbon Tetrachloride (μg/ℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
41-86	4 U	4 U	4 U	5 U
41-87	NC	NC	5 U	NA
			5 U	5 U
42-86	750	3300	PS	1695
			4835	5U
42-87	NC	5 U	PS	Dry
43-86	6	4 U	NA	2178
43-87	NC	NC	NC	NA
44-86	4 U	4 U	5 U	5 U
44-87	NC	NC	NC	PS
45-86	4 U	4 U	5 U	5 U
45-87	NC	NC	NC	5 U
46-86	4 U	4 U	5 U	PS
47-86	4 U	4 U	5 U	5 U
47-87	NC	NC	NC	5 U
48-86	4 U	4 U	5 U	5 U
48-87	NC	NC	NC	5 U
49-86	4 U	4 U	5 U	5 U
49-87	NC	NC	NC	NA
50-86	4 U	4 U	5 U	5 U
50-87	NC	NC	NC	5 U
51-86	4 U	4 U	5 U	5 U
51-87	NC	NC	NC	PS
52-86	4 U	4 U	5 U	5 U
52-87	NC	NC	NC	5 U
53-86	Dry	Dry	PS	PS
53-87	NC	NC	NC	6
54-86	4 U	4 U	4 U	Dry
54-87	NC	NC	NC	5 U
55-86	4 U	4 U	4 U	5 U
55-87	NC	NC	NC	5 U
56-86	4 U	4 U	4 U	Dry
56-87	NC	NC	NC	Dry
57-86	4 U	Dry	Dry	Dry
58-86	Dry	Dry	Dry	Dry
58-87	NC	NC	NC	NA
59-86	4 U	4 U	4 U	5 U
	4 U			
59-87	NC	NC	NC	NA
60-87	NC	NC	NC	NA
61-86	4 U	4 U	5 U	Dry
61-87	NC	NC	NC	NA
62-86	4 U	4 U	4 U	5 U
62-87	NC	NC	NC	NA
63-86	Dry	Dry	Dry	NA
63-87	NC	NC	NC	NA
64-86	4 U	4 U	4 U	NA
64-87	NC	NC	NC	NA
65-86	4 U	4 U	4 U	PS
65-87	NC	NC	NC	NA
66-86	4 U	4 U	Dry	Dry
66-87	NC	NC	NC	NA
67-86	4 U	4 U	4 U	Dry

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - Undetected. The number preceding the "U" is the detection limit of the analytical instrument.

TABLE 23. 1987 Groundwater Quarterly Sampling Program Carbon Tetrachloride (μg/ℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
67-87	NC	NC	NC	NA
68-86	4 U	4 U	4 U	Dry
68-87	NC	NC	NC	NA
69-86	4 U	4 U	4 U	5 U
70-86	4 U	4 U	4 U	5 U
70-87	NC	NC	NC	NA
71-87	NC	NC	NC	NA
72-87	NC	NC	NC	NA
WS-01	4 U	4 U	5 U	5 U
WS-02	4 U	4 U	5 U	5 U

1987 Summary

Minimum Value: Many locations below detection levels.

Maximum Value: 28000 (Well 9-74 Quarter 2)

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - Undetected. The number preceding the "U" is the detection limit of the analytical instrument.

TABLE 24. 1987 Groundwater Quarterly Sampling Program Tetrachloroethylene (μg/ℓ)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1-71	50	800	147	132
	108			
1-74	80000	528000	115	35600
1-81	4 U	4 U	4 U	5 U
				NA
1-86	4 U	4 U	4 U	NA
1-87	NC	Dry	Dry	Dry
2-60	4 U	4 U	5 U	5 U
2-71	4	440	192	NA
	1000			
2-81	4 U	4 U	PS	5 U
2-86	4 U	4 U	4 U	Dry
2-87	NC	5 U	4 U	5 U
3-74	480	1080	345	172
3-82	4 U	4 U	5 U	NA
3-86	4 U	4 U	4 U	5 U
3-87	NC	5 U	4 U	5 U
		4 U		
4-60	4 U	15	5 U	5
4-81	4 U	Dry	4 U	Dry
4-86	Dry	Dry	NA	Dry
4-87	84	Dry	4 U	6
5-82	4 U	4 U	5 U	5 U
5-86	4 U	4 U	NA	NA
5-87	NC	4 U	4 U	5 U
6-81	4 U	4 U	5 U	5 U
6-82	4 U	4 U	5 U	5 U
6-86	4 U	4 U	5 U	NA
6-87	NC	NC	PS	5 U
			5 U	
7-74	4 U	16	PS	14
			36	
7-81	4 U	4 U	5 U	5 U
7-82	Dry	Dry	Dry	NA
7-86	Dry	Dry	Dry	Dry
8-81	4 U	4 U	5 U	NA
8-86	4 U	4 U	5 U	5 U
8-87	NC	4 U	4 U	5 U
9-74	6400	13200	3393	5840
	2400			6322
9-81	4 U	4 U	5 U	NA
9-86	4 U	4 U	5 U	NA
9-87	NC	NC	NC	5 U
10-74	Dry	4 U	NA	5 U
10-81	4 U	4 U	5 U	NA
10-86	4 U	4 U	5 U	5 U
11-86	4 U	4 U	NA	Dry
11-87	NC	NC	22	NA
	NC	NC	500	NA
12-86	4 U	4 U	5 U	Dry
12-87	NC	NC	43	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - Undetected. The number preceding the "U" is the detectiion limit of the analytical instrument.

TABLE 24. 1987 Groundwater Quarterly Sampling Program Tetrachloroethylene (μg/ℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13-86	4 U	4 U	5 U	Dry
			NA	
14-86	4 U	4 U	5 U	5 U
	4 U			
14-87	NC	NC	5 U	5 U
15-86	4 U	4 U	5 U	5 U
15-87	NC	NC	900	NA
16-74	Dry	Dry	NA	Dry
16-86	4 U	4 U	5 U	5 U
16-87	NC	NC	5 U	5 U
17-86	4 U	4 U	5 U	5 U
17-87	NC	NC	NC	313
18-86	Dry	Dry	Dry	Dry
18-87	NC	NC	NC	NC
19-86	4 U	4 U	NA	10
		4 U	5 U	
19-87	NC	4 U	5 U	NA
20-86	Dry	Dry	NA	Dry
20-87	NC	NC	NC	NA
21-86	4 U	4 U	5 U	5 U
21-87	NC	NC	NC	NA
22-74	92	NA	NA	16
22-86	4 U	8	5 U	5 U
22-87	NC	NC	NC	NA
23-86	4 U	4 U	5 U	NA
23-87	NC	NC	5 U	5 U
24-86	Dry	Dry	NA	Dry
24-87	NC	NC	NC	5 U
25-86	4 U	4 U	5 U	NA
25-87	NC	NC	320	528
26-86	4 U	Dry	5 U	Dry
26-87	NC	NC	NC	5 U
27-86	4 U	4 U	5 U	5 U
	4 U			
27-87	NC	NC	NA	NA
28-86	4 U	4 U	5 U	NA
28-87	NC	NC	NA	NA
29-86	Dry	Dry	NA	NA
29-87	NC	NC	NC	99
30-86	4 U	16	5 U	NA
30-87	NC	NC	NC	NA
31-86	Dry	Dry	Dry	Dry
31-87	NC	NC	NC	5 U
32-86	4 U	4 U	5 U	5 U
	4 U			
32-87	NC	NC	NC	Dry
33-86	Dry	Dry	Dry	Dry
33-87	NC	NC	NC	NA
34-86	4 U	5 U	NA	5 U
	4 U			
34-87	NC	NC	NC	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - Undetected. The number preceding the "U" is the detection limit of the analytical instrument.

TABLE 24. 1987 Groundwater Quarterly Sampling Program Tetrachloroethylene (μg/ℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
35-86	4 U	4 U	NA	5 U
35-87	NC	NC	5 U	NA
36-86	4 U	4 U	Dry	Dry
36-87	NC	NC	5 U	4654
37-86	Dry	Dry	Dry	Dry
37-87	NC	NC	NA	Dry
38-86	4 U	4 U	NA	Dry
38-87	NC	NC	NC	NA
39-86	4 U	4 U	5 U	5 U
40-86	4 U	130	NA	5 U
40-87	NC	NC	Dry	Dry
41-86	160	4 U	11	25
41-87	NC	NC	5 U	NA
42-86	152	3200	NA	626
	NC		1040	5 U
42-87	NC	5 U	Dry	Dry
43-86	4 U	4 U	Dry	4259
43-87	NC	NC	5 U	NA
44-86	65	80	32	38
44-87	NC	NC	NC	NA
45-86	4 U	4 U	5 U	5 U
45-87	NC	NC	NC	5 U
46-86	4 U	4 U	5 U	NA
46-87	NC	NC	NC	5 U
47-86	4 U	4 U	5 U	5 U
				5 U
47-87	NC	NC	NC	5 U
48-86	4 U	4 U	5 U	5 U
48-87	NC	NC	NC	5 U
49-86	4 U	4 U	5 U	5 U
49-87	NC	NC	NC	NA
50-86	4 U	4 U	5 U	5 U
50-87	NC	NC	NC	5 U
51-86	4 U	4 U	5 U	5 U
51-87	NC	NC	NC	NA
52-86	4 U	4 U	5 U	5 U
52-87	NC	NC	NC	5 U
53-86	Dry	Dry	PS	NA
53-87	NC	NC		5 U
54-86	4 U	4 U	4 U	NA
54-87	NC	NC	NC	5 U
55-86	4 U	4 U	4 U	5 U
55-87	NC	NC	NC	5 U
			5 U	
56-86	4 U	4 U	4 U	Dry
56-87	NC	NC	NC	Dry
57-86	4 U	Dry	NA	NA
58-86	Dry	Dry	NA	NA
58-87	NC	NC	NC	NA
59-86	4 U	4 U	4 U	5 U
59-87	NC	NC	NC	NA
60-87	NC	NC	NC	NA

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - Undetected. The number preceding the "U" is the detection limit of the analytical instrument.

TABLE 24. 1987 Groundwater Quarterly Sampling Program Tetrachloroethylene (μg/ℓ) (Continued)

Well	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
61-86	4 U	4 U	5 U	PS
61-87	NC	NC	NC	NA
62-86	4 U	4 U	4 U	5 U
63-86	Dry	Dry	Dry	NA
63-87	NC	NC	NC	NA
64-86	4 U	4 U	4 U	PS
64-87	NC	NC	NC	NA
65-86	4 U	4 U	4 U 5 U	PS
65-87	NC	NC	NC	Dry
66-86	4 U	4 U	NA	Dry
66-87	NC	NC	NC	NA
67-86	4 U	4 U	4 U	Dry
67-87	NC	NC	NC	Dry
68-86	4 U	4 U	4 U	Dry
68-87	NC	NC	NC	NA
69-86	4 U	6	4 U	5 U
70-86	4 U	4 U	4 U	5 U
70-87	NC	NC	NC	NA
71-87	NC	NC	NC	NA
72-87	NC	NC	NC	NA
WS-01	136	4 U	5 U	5 U
WS-02	4 U	4 U	5 U	5 U

1987 Summary

Minimum Value: Many locations below detection levels.

Maximum Value: 528000 (Well 1-74 Quarter 2)

Dry - Well was dry.
NA - Data not available at this time.
PS - Partial Sample was collected; not enough water was available to sample.
NC - Well was not installed at this time.
U - Undetected. The number preceding the "U" is the detection limit of the analytical instrument.

corrective action measures for the high priority areas. Construction of facilities to be used for corrective actions, such as water treatment systems, is proposed to begin in the autumn of 1988.

F. Regional Water Monitoring

Regional water monitoring includes sampling and analysis of public water supplies and tap water from several surrounding communities. Only Great Western Reservoir and Standley Lake, of the regional water supplies, receive runoff from Rocky Flats Plant drainage systems (Figure 4). The Rocky Flats Plant contributions to radionuclides in regional water supplies through airborne emissions were estimated in the Plant Environmental Impact Statement.(US80a) These contributions were insignificant compared to contributions from fallout and natural background.

Water samples were collected weekly during 1987 from Great Western Reservoir, a water supply for the city of Broomfield, and from Standley Lake, a water supply for the city of Westminster and portions of the cities of Thornton and Northglenn. The weekly samples were composited into a monthly sample, and analyses were performed for plutonium, uranium, and americium concentrations. Tritium analysis was conducted for each weekly sample. Annual grab samples were also collected from three regional reservoirs (Ralston, Dillon, and Boulder) and the South Boulder Diversion Canal at distances ranging from 1.6 to 96 kilometers (1 to 60 miles) from the plant. These samples were collected to determine background data for plutonium, uranium, americium, and tritium in water. These data are presented in Tables 25 and 26.

TABLE 25. Plutonium, Uranium, and Americium Concentrations in Public Water Supplies

Location	Number of Analyses	C_{min}	C_{max}	C_{mean}	Percent of DCG
Reservoir		Plutonium Concentration ($\times 10^{-9}$ μCi/mℓ)[a]			
Boulder	1	-0.002 ± 0.03[b]	-0.002 ± 0.03[b]	-0.002 ± 0.03[c]	<0.001
Dillon	1	-0.01 ± 0.02	-0.01 ± 0.02	-0.01 ± 0.02	<0.001
Great Western	12	-0.002 ± 0.005	0.04 ± 0.06	0.007 ± 0.01	0.002
Ralston	1	-0.001 ± 0.03	-0.001 ± 0.03	-0.001 ± 0.03	<0.001
South Boulder Diversion Canal	1	0.01 ± 0.03	0.01 ± 0.03	0.01 ± 0.03	0.003
Standley	12	-0.004 ± 0.002	0.004 ± 0.001	0.004 ± 0.006	0.001
Drinking Water					
Arvada	7	-0.007 ± 0.004[b]	0.01 ± 0.03[b]	0.003 ± 0.01[c]	0.001
Boulder	12	-0.003 ± 0.002	0.03 ± 0.01	0.004 ± 0.006	0.001
Broomfield	12	-0.002 ± 0.002	0.02 ± 0.01	0.004 ± 0.006	0.001
Denver	4	-0.01 ± 0.01	0.02 ± 0.03	0.002 ± 0.02	0.001
Golden	4	-0.006 ± 0.01	0.01 ± 0.02	0.002 ± 0.01	0.001
Lafayette	4	-0.02 ± 0.01	0.01 ± 0.03	-0.001 ± 0.01	<0.001
Louisville	4	-0.007 ± 0.01	0.00 ± 0.03	-0.005 ± 0.01	<0.001
Thornton	4	-0.01 ± 0.01	0.002 ± 0.03	-0.008 ± 0.01	<0.001
Westminster	12	-0.003 ± 0.002	0.02 ± 0.01	0.002 ± 0.002	0.001
Reservoir		Uranium Concentration ($\times 10^{-9}$ μCi/mℓ)[d]			
Boulder	1	0.7 ± 0.1[b]	0.7 ± 0.1[b]	0.7 ± 0.1[c]	0.1
Dillon	1	1.0 ± 0.1	1.0 ± 0.1	1.0 ± 0.1	0.2
Great Western	12	1.8 ± 0.2	4.9 ± 0.5	2.5 ± 0.1	0.5
Ralston	1	1.7 ± 0.1	1.7 ± 0.1	1.7 ± 0.1	0.3
South Boulder Diversion Canal	1	0.4 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	0.1
Standley	12	0.3 ± 0.1	2.7 ± 0.3	1.7 ± 0.1	0.3
Drinking Water					
Arvada	7	-0.01 ± 0.02[b]	0.6 ± 0.1[b]	0.3 ± 0.03[c]	0.1
Boulder	12	-0.01 ± 0.08	1.2 ± 0.2	0.2 ± 0.03	0.04
Broomfield	12	0.5 ± 0.1	1.7 ± 0.2	1.2 ± 0.2	0.2
Denver	4	0.2 ± 0.1	1.4 ± 0.2	0.7 ± 0.1	0.1
Golden	4	0.6 ± 0.1	1.8 ± 0.3	1.1 ± 0.2	0.2
Lafayette	4	0.1 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.04
Louisville	4	-0.03 ± 0.1	0.1 ± 0.1	0.04 ± 0.05	0.01
Thornton	4	1.1 ± 0.2	4.6 ± 0.6	3.5 ± 0.2	0.7
Westminster	12	0.01 ± 0.04	1.9 ± 0.2	0.6 ± 0.1	0.1

a. Radiochemically determined as plutonium-239 and -240. The interim standard calculated Derived Concentration Guide (DCG) for plutonium in water available to members of the public is 300×10^{-9} μCi/mℓ. (See Appendix A.)
b. Calculated as 1.96 standard deviations of the individual measurements.
c. Calculated as 1.96 standard deviations of the mean.
d. Radiochemically determined as uranium-233, -234, and -238. The interim standard calculated Derived Concentration Guide (DCG) for uranium in water available to members of the public is 500×10^{-9} μCi/mℓ. (See Appendix A.)
e. Radiochemically determined as americium-241. The interim standard calculated Derived Concentration Guide (DCG) for americium in water available to members of the public is 60×10^{-9} μCi/mℓ. (See Appendix A.)

TABLE 25. Plutonium, Uranium, and Americium Concentrations in Public Water Supplies (Continued)

Location	Number of Analyses	C_{min}	C_{max}	C_{mean}	Percent of DCG
		Americium Concentration ($\times 10^{-9}$ μCi/mℓ)[c]			
Reservoir					
Boulder	1	-0.003 ± 0.2[b]	-0.003 ± 0.02[b]	-0.003 ± 0.02[c]	<0.001
Dillon	1	0.000 ± 0.002	0.000 ± 0.02	0.000 ± 0.02	<0.001
Great Western	12	-0.01 ± 0.01	0.02 ± 0.01	0.002 ± 0.003	0.003
Ralston	1	0.01 ± 0.02	0.01 ± 0.02	0.01 ± 0.02	0.02
South Boulder Diversion Canal	1	0.02 ± 0.02	0.02 ± 0.02	0.02 ± 0.02	0.03
Standley	12	-0.01 ± 0.01	0.01 ± 0.01	0.002 ± 0.002	0.003
Drinking Water					
Arvada	7	-0.01 ±0.02[b]	0.02 ± 0.02[b]	0.005 ± 0.004[c]	0.008
Boulder	12	-0.003 ± 0.003	0.02 ± 0.01	0.005 ± 0.002	0.008
Broomfield	12	-0.01 ± 0.01	0.01 ± 0.02	0.002 ± 0.002	0.003
Denver	4	-0.006 ± 0.02	0.02 ± 0.02	0.007 ± 0.02	0.01
Golden	4	-0.002 ± 0.02	0.04 ± 0.03	0.02 ± 0.02	0.03
Lafayette	4	-0.003 ± 0.02	0.007 ± 0.02	0.001 ± 0.02	0.002
Louisville	4	-0.004 ± 0.02	0.04 ± 0.02	0.01 ± 0.02	0.02
Thornton	4	-0.01 ± 0.05	0.04 ± 0.02	0.01 ± 0.02	0.02
Westminster	12	-0.001 ± 0.003	0.06 ± 0.01	0.007 ± 0.003	0.01

a. Radiochemically determined as plutonium-239 and -240. The interim standard calculated Derived Concentration Guide (DCG) for plutonium in water available to members of the public is 300×10^{-9} μCi/mℓ. (See Appendix A.)
b. Calculated as 1.96 standard deviations of the individual measurements.
c. Calculated as 1.96 standard deviations of the mean.
d. Radiochemically determined as uranium-233, -234, and -238. The interim standard calculated Derived Concentration Guide (DCG) for uranium in water available to members of the public is 500×10^{-9} μCi/mℓ. (See Appendix A.)
e. Radiochemically determined as americium-241. The interim standard calculated Derived Concentration Guide (DCG) for americium in water available to members of the public is 60×10^{-9} μCi/mℓ. (See Appendix A.)

TABLE 26. Tritium Concentrations in Public Water Supplies

Location	Number of Analyses	C_{min}	C_{max}	C_{mean}	Percent of DCG
Reservoir		Tritium Concentration ($\times 10^{-9}$ μCi/mℓ)[a]			
Boulder	1	400 ± 400[b]	400 ± 400[b]	400 ± 400[c]	0.02
Dillon	1	700 ± 400	700 ± 400	700 ± 400	0.04
Great Western	48	-700 ± 100	800 ± 500	100 ± 60	0.005
Ralston	1	200 ± 400	200 ± 400	200 ± 400	0.01
South Boulder Diversion Canal	1	300 ± 400	300 ± 400	300 ± 400	0.02
Standley	48	-300 ± 100	500 ± 600	100 ± 60	0.005
Drinking Water					
Arvada	4	0 ± 400[b]	900 ± 500[b]	400 ± 220[c]	0.02
Boulder	48	-700 ± 100	900 ± 500	100 ± 60	0.005
Broomfield	48	-600 ± 100	1020 ± 500	100 ± 60	0.005
Denver	4	-300 ± 400	700 ± 500	100 ± 210	0.005
Golden	4	-300 ± 400	0 ± 400	-200 ± 210	<0.001
Lafayette	4	-200 ± 200	700 ± 400	200 ± 210	0.01
Louisville	4	-100 ± 200	500 ± 400	200 ± 210	0.01
Thornton	4	100 ± 200	2000 ± 500	700 ± 220	0.04
Westminster	48	-600 ± 100	800 ± 500	100 ± 130	0.005

a. The Derived Concentration Guide (DCG) for tritium in water available to members of the public is 2,000,000 X 10^{-9} μCi/mℓ. The EPA and State of Colorado Primary Drinking Water Regulation limits for tritium are 20,000 X 10^{-9} μCi/mℓ.
b. Calculated as 1.96 standard deviations of the individual measurements.
c. Calculated as 1.96 standard deviations of the mean.

Drinking water from Boulder, Broomfield, and Westminster was collected weekly, preserved, composited monthly, and analyzed for plutonium, uranium, and americium. Tritium analyses were performed on weekly grab samples. Quarterly grab samples of tap water were collected from the surrounding communities of Arvada, Denver, Golden, Lafayette, Louisville, and Thornton. Samples were analyzed for plutonium, uranium, americium, and tritium. These data are presented in Tables 25 and 26.

Evaluation of the regional reservoir and drinking water data indicates no unusual results. The plutonium, uranium, americium, and tritium concentrations for the regional reservoirs represented a small fraction (0.5 percent or less) of the DOE Derived Concentration Guides (DCGs). The average plutonium concentration in Great Western Reservoir was 0.007 X 10^{-9} μCi/mℓ (2.6 X 10^{-4} Bq/ℓ). This value is in the range of concentrations predicted for Great Western Reservoir in the Plant Environmental Impact Statement.(US80a) The values given in the Environmental Impact Statement are based on known low-level plutonium concentrations in the reservoir sediments. Results of the 1987 plutonium, uranium, americium, and tritium data for drinking water in nine communities were within the background range. All drinking water values were 0.7 percent or less of the applicable DCG.

Drinking water standards have been adopted by the State of Colorado(Co77, Co81) and the Environmental Protection Agency (EPA)(US76a) for alpha-emitting radionuclides (excluding uranium and radon) and for tritium. These standards are 15 X 10^{-9} μCi/mℓ and 20,000 X 10^{-9} μCi/mℓ (5.55 X 10^{-1} Bq/ℓ and 740 Bq/ℓ) respectively. During 1987, the sum of the average concentrations of plutonium and americium (alpha-emitting radionuclides) for each community tap water location was 0.022 X 10^{-9} μCi/mℓ (8.1 X 10^{-4} Bq/ℓ) or less. This value is 0.1 percent or less of the EPA and State of Colorado drinking water standard for alpha activity. The average tritium concentration in Great Western Reservoir, Standley Lake, and in all community tap water samples was 700 X 10^{-9}

TABLE 27. Plutonium Concentration[a] in Rocky Flats Area Soil Samples[b] at One and Two Miles From the Plant Center, 1984-1987

Location	1984 Pu (pCi/g)[c]	1985 Pu (pCi/g)[c]	1986 Pu (pCi/g)[c]	1987 Pu (pCi/g)[c]
1-018	0.08 ± 0.02[d]	0.15 ± 0.02	0.15 ± 0.02	0.18 ± 0.02
1-036	0.03 ± 0.01	0.08 ± 0.01	0.10 ± 0.02	0.06 ± 0.01
1-054	0.00 ± 0.01	0.02 ± 0.01	0.04 ± 0.01	0.04 ± 0.01
1-072	0.06 ± 0.05	0.32 ± 0.03	0.63 ± 0.06	0.51 ± 0.05
1-090	7.7 ± 0.5	1.0 ± 0.09	7.4 ± 0.62	7.05 ± 0.77
1-108	15.0 ± 0.9	13.0 ± 1.3	15.0 ± 1.4	2.37 ± 0.21
1-126	2.1 ± 0.1	1.9 ± 0.17	1.9 ± 0.18	2.75 ± 0.28
1-144	0.29 ± 0.03	0.32 ± 0.03	0.27 ± 0.02	0.36 ± 0.04
1-162	0.14 ± 0.02	0.10 ± 0.01	0.08 ± 0.01	0.17 ± 0.02
1-180	0.09 ± 0.02	0.06 ± 0.01	0.06 ± 0.01	0.10 ± 0.01
1-198	0.22 ± 0.03	0.16 ± 0.02	0.16 ± 0.02	0.21 ± 0.02
1-216	0.05 ± 0.02	0.05 ± 0.01	0.10 ± 0.01	0.16 ± 0.02
1-234	0.13 ± 0.02	0.05 ± 0.01	0.04 ± 0.01	0.05 ± 0.01
1-252	0.17 ± 0.02	0.14 ± 0.02	0.11 ± 0.01	0.21 ± 0.03
1-270	0.06 ± 0.02	0.07 ± 0.01	0.08 ± 0.01	0.09 ± 0.01
1-288	0.04 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.06 ± 0.01
1-306	0.14 ± 0.02	0.09 ± 0.01	0.17 ± 0.02	0.21 ± 0.03
1-324	0.13 ± 0.02	0.15 ± 0.02	0.21 ± 0.02	0.24 ± 0.03
1-342	0.04 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0.01
1-360	0.10 ± 0.02	0.11 ± 0.01	0.19 ± 0.02	0.16 ± 0.02
2-018	0.00 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	0.04 ± 0.01
2-036	0.02 ± 0.01	0.02 ± 0.01	0.07 ± 0.01	0.10 ± 0.01
2-054	0.03 ± 0.01	0.03 ± 0.01	0.05 ± 0.01	0.10 ± 0.01
2-072	0.40 ± 0.04	0.33 ± 0.03	0.23 ± 0.02	0.36 ± 0.04
2-090	10.0 ± 0.6	2.5 ± 0.25	5.3 ± 0.48	4.48 ± 0.52
2-108	0.46 ± 0.04	0.41 ± 0.04	0.46 ± 0.04	0.57 ± 0.06
2-126	0.14 ± 0.02	0.42 ± 0.04	0.44 ± 0.05	0.40 ± 0.04
2-144	0.02 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.08 ± 0.01
2-162	0.00 ± 0.01	0.01 ± 0.00	0.02 ± 0.01	0.03 ± 0.01
2-180	0.02 ± 0.01	0.11 ± 0.01	0.04 ± 0.01	0.03 ± 0.01
2-198	0.05 ± 0.02	0.02 ± 0.01	0.08 ± 0.01	0.14 ± 0.02
2-216	0.04 ± 0.01	0.04 ± 0.01	0.06 ± 0.01	0.07 ± 0.01
2-234	0.04 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.07 ± 0.01
2-252	0.09 ± 0.01	0.04 ± 0.01	0.07 ± 0.01	0.06 ± 0.01
2-270	0.04 ± 0.01	0.04 ± 0.01	0.06 ± 0.01	0.08 ± 0.01
2-288	0.01 ± 0.01	0.04 ± 0.01	0.05 ± 0.01	0.13 ± 0.02
2-306	0.00 ± 0.01	0.06 ± 0.01	0.02 ± 0.01	0.08 ± 0.01
2-324	0.08 ± 0.02	0.04 ± 0.01	0.09 ± 0.01	0.08 ± 0.01
2-342	0.13 ± 0.02	0.13 ± 0.01	0.12 ± 0.01	0.14 ± 0.02
2-360	0.02 ± 0.01	0.09 ± 0.01	0.05 ± 0.01	0.08 ± 0.01

a. Not blank corrected.
b. Sampled to a depth of 5 cm.
c. Concentrations are for the fraction of soil measuring less than 2mm in diameter.
d. Error term represents 2 standard deviations.

μCi/mℓ (26 Bq/ℓ) or less. That value represents 3.5 percent or less of the State of Colorado and EPA Drinking Water Standard for tritium.(Co81, US76a)

G. Soil Sampling and Analysis

Forty soil samples were collected in September 1987 at radial intervals of approximate distances of 1.6 and 3.2 kilometers (1 and 2 miles) from the center of the plant. The soil samples were collected by driving a 10 X 10 centimeter (4 X 4 inches) cutting tool 5 centimeters (2 inches) into undisturbed soil.(Ro86) The soil sample within the tool cavity was collected and placed into a new one-gallon metal can. Five subsamples were collected from the corners and center of two one-meter squares, which were spaced one meter apart. Each set of ten subamples was composited for the plutonium radiochemical analysis.

The 1987 soil plutonium data are summarized in Table 27 and displayed in Figure 13. The concentrations of soil plutonium at the 1.6 kilometer (1 mile) distance from the plant center ranged from 0.03 to 7.05 pCi/g (1.11 to 261 Bq/kg). The concentrations of soil plutonium for the 3.2 kilometer (2 mile) samples ranged from 0.03 to 4.48 pCi/g (1.11 to 166 Bq/kg). The maximum plutonium values were found in the soil samples from the eastern portion of the buffer zone. These sample locations are east and southeast (generally downwind) of the major source of plutonium contamination at the 903 Pad Area. The plutonium concentrations measured in 1987 were similar to the values measured in 1984, 1985 and 1986. Data for 1984, 1985 and 1986 are included in Table 27 for comparison. Variability in concentrations from year to year for sampling at the same site is to be expected. Samples are collected from the area around a sampling location, never more than 100 feet from the located sampling point. To sample the same location exactly from year to year is not desirable, since that location would have been disturbed by the previous years sampling. Since the sampling from year to year is from slightly different locations, the effect of non-uniform deposition by wind, redistribution of plutonium by erosion or faunal activities, and sampling and analytical error will all contribute to variability.

H. External Gamma Radiation Dose Monitoring

Thermoluminescent dosimeters (TLDs) are used to measure external penetrating gamma radiation exposure at 47 locations on and off the plantsite. Replicate TLDs are located at each site. All TLDs are exposed for three months. The TLDs are placed at 19 locations within the property enclosed by the security fence. Measurements are also made at 16 perimeter locations 3 to 6 kilometers (2 to 4 miles) from the center of the plant and in 12 communities located within 50 kilometers (30 miles) of the plant. The TLDs are placed at a height of 1 meter (3 feet) above ground level.

During 1983, conversion from a Harshaw TLD system to a Panasonic system was initiated. For one complete calendar year, two TLDs of each type were used at each monitoring location. Beginning in 1984, only the Panasonic TLDs were used.

The environmental TLDs consist of two Panasonic 802 dosimeters, each of which has four elements. Only one of the elements of each dosimeter is used. This element consists of calcium sulfate, thulium drifted ($CaSO_4$:Tm), deposited on a polymid surface. The phosphor is covered with a clear teflon and backed with an opaque ABS plastic. The TLDs are packaged in a small plastic bag, a paper envelope, and another plastic bag to protect them from the weather. Total filtration over the phosphor is 178.5 mg/cm^2.

The environmental dosimeters have been individually calibrated (three times each) against an onsite Cs-137 gamma calibration source. Calibration linearity studies have confirmed that TLD response is linear for exposure levels ranging from 10 mrem to 1000 mrem. The mean calibration factor for each dosimeter is applied to measurements taken with that dosimeter. An additional correction is applied to correct for day to day variations in reader calibration.

It was determined that a statistically significant ($p=0.05$) difference in response exists between the

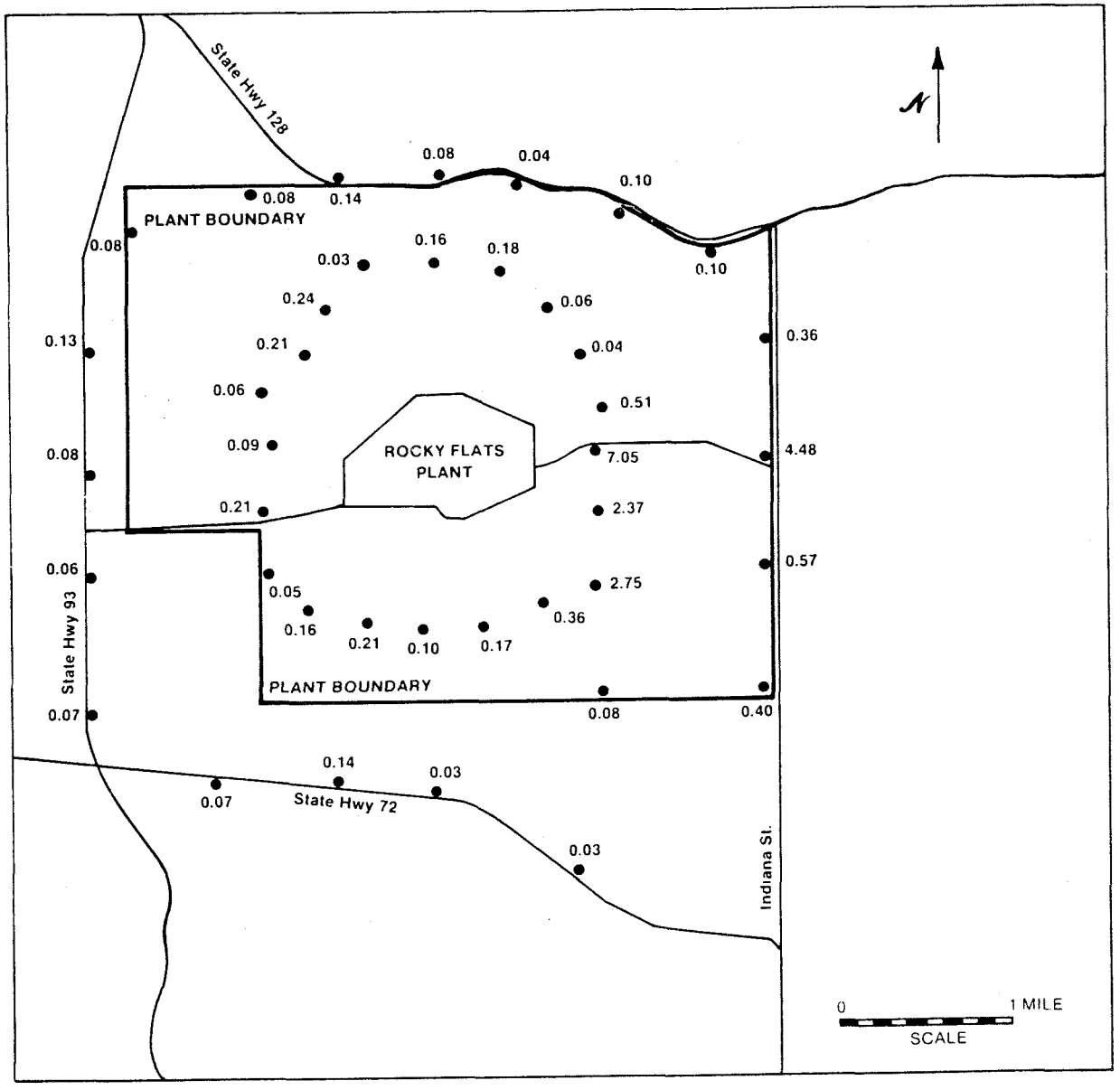


FIGURE 13. Plutonium Concentrations in Soil
(Values in Picocuries Per Gram)

TABLE 28. Environmental Thermoluminescent Dosimeter Measurements

Location Category	Number of Locations	Number of Measurements	Mean Annual Measured Dose (mrem)[a]	95% Confidence Interval on the Mean (mrem)[b]	95% Confidence Interval on an Individual Measurement (mrem)[c]
Onsite	19	100	153	± 4	± 36
Perimeter	16	66	138	± 4	± 29
Community	12	51	157	± 6	± 43

a. Third quarter measurements were not used in calculating the mean measured dose for each location category.
b. Calculated as 1.96 standard deviations of the mean.
c. Calculated as 1.96 standard deviations of the individual measurements.

Harshaw environmental monitoring system used prior to 1984, and the Panasonic environmental monitoring systems used beginning in 1984. In order to compare the 1987 values with the previously reported Harshaw data, it is necessary to multiply the Panasonic results given in Table 28 by 1.046.

The annual dose equivalent for each location category was calculated by determining the average mrem/day for each of the three categories using data from Quarters 1, 2, and 4. These values were then multiplied by 365.25 to obtain yearly totals. The dosimeter data collected during Quarter 3 were invalidated due to a Panasonic reader malfunction.

In previous Annual Reports, the Annual Measured Dose was reported with a 95 percent confidence interval on the mean using the standard error of the mean, calculated from the variance of the individual measured values. Beginning in 1985, the 95 percent confidence interval on an individual observation within each location category - calculated as 1.96 standard deviations - was added to the report. This latter interval may be used for assessing the variability of the individual location measurements within a location category.

The 1987 environmental measurements using TLDs are summarized in Table 28. The average annual dose equivalents, as measured onsite, in the perimeter environs, and in communities, were 153, 138, and 157 mrem (1.53, 1.38, and 1.57 mSv), respectively. These values are indicative of background radiation in the area.

V. ASSESSMENT OF POTENTIAL PLANT CONTRIBUTION TO PUBLIC RADIATION DOSE

In August 1985, the Department of Energy (DOE) adopted an interim radiation protection standard for DOE environmental activities to be implemented in CY1985.(Va85) This interim standard incorporates guidance from the National Council on Radiation Protection and Measurements (NCRP), as well as the Environmental Protection Agency Clean Air Act air emission standards as implemented in 40 CFR 61, Subpart H.(US83, US85) Included in the interim standard is a revision of the dose limits for members of the public and tables of radiation dose conversion factors to be used for calculating dose from intakes of radioactive materials. The dose factors are based on the International Commission on Radiological Protection (ICRP) Publication 30 methodology for radiation dosimetry. The DOE interim standard and the dose conversion factor tables have been used in this 1987 "Annual Environmental Monitoring Report" for assessment of the potential Rocky Flats Plant contribution to public radiation dose. As in past Annual Reports, the dose limits and dose conversion factors used are specified, and comparisons can be made with information in past Annual Reports to determine the magnitude of the changes.

Potential public radiation dose commitments, which could have resulted from plant operations, were calculated from average radionuclide concentrations measured at the DOE property boundary and in surrounding communities. Inhalation, water

TABLE 29. Isotopic Composition of Plutonium Used at the Rocky Flats Plant(US80a)

Isotope	Relative Weight (Percent)	Specific Activity (Ci/g)	Relative Activity[a] (Ci/g)	Fraction of Pu Alpha Activity[b]
Pu-238	0.01	17.1	0.00171	0.0233
Pu-239	93.79	0.0622	0.05834	0.7962
Pu-240	5.80	0.228	0.01322	0.1804
Pu-241	0.36	103.5*	0.37260*	5.085*
Pu-242	0.03	0.00393	1.18×10^{-6}	1.61×10^{-5}
Am-241	–	–	–	0.20[c]

*Beta Activity.

a. Obtained by multiplying the percent by weight by the specific activity.
b. Obtained by dividing the relative activity by the sum of the relative activities for the plutonium alpha emitters.
c. The value for Am-241 is taken to be 20% of the plutonium alpha activity.

TABLE 30. Dose Conversion Factors Used in Dose Assessment Calculations

	Inhalation[a, b] $\left(\frac{\text{rem·milliliter}}{\text{microcurie}}\right)$	Water Ingestion[a, c] $\left(\frac{\text{rem·milliliter}}{\text{microcurie}}\right)$			Ground-Plane Irradiation[d] $\left(\frac{\text{rem·square meter}}{\text{microcurie}}\right)$	
Organ	Pu-239, -240	Pu-239, -240	Am-241	U-233, -234, -238	Pu-239, -240	Am-241
Effective Dose Equivalent	5.57×10^{12}	3.14×10^{5}	1.63×10^{6}	1.68×10^{5}	8.92×10^{-5}	3.05×10^{-3}
Liver	2.17×10^{13}	1.17×10^{6}	6.21×10^{6}	(e)	4.85×10^{-6}	1.78×10^{-3}
Bone Surfaces	1.02×10^{14}	5.69×10^{6}	2.97×10^{7}	2.70×10^{6}	2.01×10^{-5}	3.69×10^{-3}
Lung	1.06×10^{13}	(f)	(f)	(f)	1.20×10^{-5}	2.01×10^{-3}

a. Inhalation and water ingestion dose conversion factors were adopted from DOE and are for a 50-year dose commitment period and a 1-μm Activity Median Aerodynamic Diameter (AMAD) particle size.(Va85) GI absorption fractions and lung clearance classes were chosen to maximize the dose converion factors.
b. An inhalation rate of 2.66×10^{2} mℓ/s for 1 year was assumed.
c. A water intake rate of 2×10^{3} mℓ (2.1 quarts) per day for 1 year was assumed.
d. Ground plane irradiation dose conversion factors were adopted from D. C. Kocher.(Ko81, Ko83) For Pu-239, -240, the higher of the factors for the two isotopes was used.
e. The liver receives no significant dose from this pathway.
f. The lung receives no significant dose from this pathway.

ingestion. and ground-plane irradiation are the principal pathways of exposure. Swimming and consumption of foodstuffs are insignificant pathways. This latter finding is to be expected because of limited swimming and fishing in the area and because most locally consumed food is produced at considerable distances from the plant.

The dose assessment for 1987 was conducted for several locations: the Rocky Flats Plant property (site) boundary, nearby communities, and sites to a distance of 80 kilometers (50 miles). Dose conversion factors used for the inhalation and water ingestion pathways were derived from the tables provided by DOE.(Va85) The relative abundances of plutonium and americium isotopes in plutonium used at Rocky Flats (shown in Table 29) were used to calculate composite dose conversion factors for inhalation. The fractions of ingested radionuclides that are absorbed from the gastrointestinal tract and the lung clearance classes for inhaled radionuclides were chosen to maximize the associated dose conversion factors. The inhalation rate of 2.66×10^{-4} m^3/s and the water ingestion rate of 2 liters (2.1 quarts) per day were derived from data for reference man and were included in the factors.(In75) Each of these dose conversion factors is for a 50-year dose commitment from one year of chronic exposure. Ground-plane irradiation dose conversion factors are from published data by D. C. Kocher.(Ko81, Ko83) The dose conversion factors used in this report are listed in Table 30.

A. Dose Assessment Source Terms

Plutonium and americium in the Rocky Flats environs are the combined result of fallout deposition from global atmospheric nuclear weapons testing and past releases from the plant. Uranium, a naturally occurring element, is indigenous to many parts of Colorado and also is used in plant operations in various isotopic ratios. Tritium, a radionuclide formed by natural processes, also is associated with plant operations.

Inhalation source terms for the 1987 dose assessment were based on plutonium-239 and -240 concentrations measured in ambient air samples. Although it is known that much of this plutonium in air is from residual fallout from past global atmospheric weapons testing, for the purpose of this dose assessment it was assumed that all of the plutonium originated from the Rocky Flats Plant. The ingestion source terms were based on measured concentrations of plutonium, americium, uranium, and tritium in water. The ground-plane source terms were based on measured values of plutonium in soil and an assumed ratio of 0.20 for the americium to plutonium alpha activity in the soil. This ratio is the maximum level of americium in-growth from Rocky Flats Plant plutonium.(US80a)

The maximum plant site-boundary dose assessment assumes that an individual is continuously present at the plant perimeter, which actually is uninhabited. The plutonium inhalation source term of 2.4×10^{-17} μCi/mℓ (8.9×10^{-7} Bq/m^3) was the maximum annual average concentration of plutonium-239 and -240, as measured for a single location in the perimeter ambient air sampling network.

The water supply for the individual at the site boundary was assumed to be Walnut Creek, which intermittenly flows offsite and provides the liquid effluent source term at the site boundary. During 1987, the plutonium concentration in Walnut Creek averaged 2×10^{-11} μCi/mℓ (7×10^{-4} Bq/ℓ). The average americium concentration was 1×10^{-11} μCi/mℓ (4×10^{-4} Bq/ℓ). These concentrations were used as the water ingestion source term for the maximum site boundary dose assessment. The average concentration of uranium in Walnut Creek was 3.8×10^{-9} μCi/mℓ (1.4×10^{-1} Bq/ℓ) while the average concentration in incoming raw water was 9.4×10^{-10} μCi/mℓ (3.5×10^{-2} Bq/ℓ). The source term for uranium ingestion was the difference between these two values [2.9×10^{-9} μCi/mℓ (1.1×10^{-1} Bq/ℓ)]. The average tritium concentration in Walnut Creek was 4×10^{-7} μCi/mℓ (14.8 Bq/ℓ), which is within the background range typically measured in regional waters. This concentration of tritium is an insignificant contributor to dose. Tritium in the water was, therefore, omitted from the dose assessement.

The ground-plane irradiation source term is based on the maximum plutonium in soil deposition at the plant perimeter, as reported by the Environmental Measurements Laboratory.(US70) This source term is 3×10^{-2} μCi/m^2 (1×10^3 Bq/m^2). The americium is assumed to be present at an alpha activity level of 20 percent of that of the plutonium which is the maximum quantity of americium that can be present in Rocky Flats Plant plutonium from the decay of plutonium-241.(US80a) The americium source term, therefore, is conservatively estimated to be 6×10^{-3} μCi/m^2 (2×10^2 Bq/m^2).

Source terms and corresponding dose commitments were evaluated for each of the surrounding communities to determine the maximum community exposure. Ground-plane irradiation and water ingestion pathways were insignificant for all of the communities. The only significant pathway for radiation exposure was inhalation of plutonium in air. The source term for inhalation used in the dose assessment was the maximum annual average plutonium concentration measured in community ambient air [2.6×10^{-17} μCi/mℓ (9.6×10^{-7} Bq/m^3)]. This concentration was the annual average concentration measured in the Golden ambient air sampler.

A summary of the source terms for the maximum site boundary and for community locations is tabulated in Table 31.

B. Maximum Site Boundary Dose

The maximum dose to an individual continuously present at the site boundary is based on the radionuclide concentrations shown in Table 31. From

TABLE 31. Radioactivity Concentrations Used for 1987 Dose Calculations

	Air (μCi/mℓ)	Water (μCi/mℓ)			Surface Deposition (μCi/m^2)	
Location	Pu-239, -240	Pu-239, -240	Am-241	U-233, -234	Pu-239, -240	Am-241
Maximum Site Boundary	2.4×10^{-17}	2.0×10^{-11}	1.0×10^{-11}	2.9×10^{-9}	3×10^{-2}	6×10^{-3}
Community	2.6×10^{-17}	–	–	–	–	–

TABLE 32. Fifty-Year Committed Dose Equivalent From One Year of Chronic Intake/Exposure

Source	Effective Dose Equivalent (rem)	Liver (rem)	Bone Surfaces (rem)	Lung (rem)
Maximum Site Boundary Location	6.6×10^{-4}	6.2×10^{-4}	1.1×10^{-2}	2.7×10^{-4}
Community	1.4×10^{-4}	5.6×10^{-4}	2.7×10^{-3}	2.8×10^{-4}

these concentrations and the dose conversion factors in Table 30, a 50-year dose commitment of 6.6×10^{-4} rem (6.6×10^{-6} Sv) is calculated as the effective dose equivalent from all pathways. The corresponding bone surfaces dose is 1.1×10^{-2} rem (1.1×10^{-4} Sv). The Department of Energy (DOE) interim radiation protection standard for members of the public for prolonged periods of exposure is 0.1 rem per year (1×10^{-3} Sv per year) effective dose equivalent. The interim standard for the air pathway only is 7.5×10^{-2} rem per year (7.5×10^{-4} Sv per year) for any organ for internally deposited radionuclides.(Va85) The maximum site boundary dose represents 0.66 percent of the standard for all pathways for the effective dose equivalent. If all of the dose were received from the air pathway, it would represent less than 15 percent of the air emission standard for any organ.

C. Maximum Community Dose

Based on radionuclide concentrations in surrounding communities (Table 31), the calculated 50-year dose commitments are 1.4×10^{-4} rem (1.4×10^{-6} Sv) effective dose equivalent and 2.7×10^{-3} rem (2.7×10^{-5} Sv) to bone surfaces. These values represent 0.14 percent of the DOE interim standard for effective dose equivalent and 3.6 percent of the air emission standard for any organ.

The maximum site boundary and community 50-year committed dose equivalents are summarized in Table 32. The effective dose equivalents may be compared to an average annual effective dose equivalent for the Denver area of about 3.5×10^{-1} rem (3.5×10^{-3} Sv) from natural background radiation.(Na87) (See Table 33.) This natural background radiation level for Denver is higher than that shown for the total body in past Annual Reports prior to 1985 and also higher than that shown for effective dose equivalent in the 1985 and 1986 Annual Reports. The level reflects the most recent assessment of natural background radiation exposure of the population of the United States by the National Council on Radiation Protection and Measurements (NCRP). It includes the significant contribution to effective dose equivalent from inhaled indoor radon, as well as the adoption of the ICRP 30 methodology of radiation dosimetry. The cosmic radiation and external primordial nuclides sources shown in Table 33 reflect the regional dose levels for the Denver area which result from Denver's higher elevation and greater concentrations of naturally-occurring radioactive materials in soil. The internal primordial nuclide source includes the average dose

TABLE 33. Estimated Annual Natural Background Radiation Dose for the Denver Metropolitan Area(Na87)

Source	Effective Dose Equivalent (rem)
Cosmic Radiation	0.050
Cosmogenic Nuclides	0.001
Primordial Nuclides-External	0.063
Primordial Nuclides-Internal	0.239
Total for one year (rounded)	0.35

from indoor radon estimated by the NCRP for the entire United States. Studies are now being conducted by the EPA and others to determine any regional differences in indoor radon doses that may exist. Once these studies are completed, the estimates of natural background radiation doses for the Denver area may be modified again to reflect indoor radon doses that are specific to this region.

D. Eighty-Kilometer Dose Estimates

The dose commitment for all individuals, to a distance of 80 kilometers (50 miles), is based on the calculated maximum community dose estimates shown in Table 32. The estimated committed effective dose equivalent is less than 1×10^{-3} rem or 1 mrem (1×10^{-5} Sv). A level of "1 mrem/yr" or less is specified as a *de minimis* (inconsequential) level of exposure in the DOE Guide entitled, "A Guide to Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA)."(US80b) The Guide further states:

> "Radiation-induced mutations and diseases have not been discovered in populations that are or have been exposed to doses of 100 mrem/yr or less. Hence, it is reasonable to suggest that no health effects will be discerned if a population is exposed to an additional 1 percent of the level; i.e., 1 mrem/yr. An annual dose of 1 mrem should be regarded as a level which is clearly *de minimis*."

Based on the *de minimis* concept in the Guide and on the maximum community dose estimates, the dose commitment for all individuals to 80 kilometers is considered to be *de minimis*.

The Environmental Protection Agency (EPA) requires that approved EPA procedures be used to demonstrate compliance with its radioactivity air emissions standards found in 40 CFR 61, Subpart H. At the writing of this Report, the only procedure for which the EPA has published approval is modeling of radioactivity air emissions data using the AIRDOS-EPA atmospheric dispersion/radiation dose calculation computer code:(US85) The Rocky Flats Plant is seeking EPA approval for using environmental (ambient) sampling as the basis for demonstrating compliance with 40 CFR 61, Subpart H. This is the procedure that is described above for calculating projected radiation doses to the public. Pending EPA approval of this procedure, the AIRDOS-EPA computer code also has been used to calculate projected radiation doses to the public as a result of air emissions of radioactive materials from the Rocky Flats Plant. The results of this computer code calculation confirm that the maximum radiation dose to a member of the public as a result of exposure to airborne radioactivity from the Rocky Flats Plant in 1987 is less than 1 mrem effective dose equivalent.

VI. APPENDIXES

APPENDIX A
APPLICABLE GUIDES AND STANDARDS

The Rocky Flats Plant Environmental Monitoring Program includes evaluating plant compliance with all relevant guides, limits, and standards. Guide values for radionuclides in ambient air and waterborne effluents have been adopted by the Department of Energy (DOE), the Colorado Department of Health (CDH), and for the air pathway only by the Environmental Protection Agency (EPA).(Va85, Co78) The guides are based on recommendations published by the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). Ambient air data for nonradioactive parameters is collected at the Rocky Flats Plant for comparison to the criteria pollutants listed under the EPA National Ambient Air Quality Standards, established by the Clean Air Act.(US81b) Instrumentation and methodology follow requirements established by EPA in the Quality Assurance Handbook for Air Pollution Measurement Systems.(US76b) Limits for nonradioactive pollutants in effluent water have been defined by an EPA National Pollutant Discharge Elimination System (NPDES) discharge permit.(US84a) In 1976, the EPA also established standards for radionuclides in drinking water.(US76a) These drinking water standards have been adopted, in turn, by the State of Colorado.(Co77, Co81) In 1973, Colorado first enacted the Colorado Water Quality Control Act.(Co73) Standards for implementation of this Act were first enacted in 1974 and currently include provisions for protection of Colorado waterways from both radioactive and non-radioactive contaminants.(Co87)

In a memorandum of August 5, 1985, the DOE adopted an interim radiation protection standard for DOE environmental activities to be implemented in CY 1985.(Va85) This interim standard incorporates guidance from the NCRP, as well as the EPA Clean Air Act air emission standards for radioactive emissions, as implemented in 40 CFR 61, Subpart H.(US83, US85) Included in the interim standard is a revision of the dose limits for members of the public and tables of radiation dose conversion factors to be used for calculating dose from intakes of radioactive materials. Table A-1 summarizes the interim radiation dose limits for members of the public. The dose factors are based on ICRP Publication 30 methodology for radiation dosimetry. Effluent air and water Derived Concentration Guides (secondary guides derived from the primary dose standards and calculated using dose conversion factors and assumed air and water intake rates) were provided later in a February 28, 1986, memorandum.(St86) The calculated Derived Concentration Guides (DCGs) are based on the interim standard dose limit for all pathways of 0.1 rem/year for a 50-year committed effective dose equivalent. The dose conversion factors provided in the August 5, 1985, memorandum were used and intake rates of 8400 cubic meters per year (2.66×10^{-4} m^3/s) for air and 730 liters per year (2 ℓ/d) for water were assumed for the calculations. The DCGs are given in Table A-2 and are comparable in concept to the Radioactivity Concentration Guides (RCGs) published by DOE for its previous radiation protection standard given in DOE Order 5480.1A, Chapter XI. (US81a)

The previous RCGs included permissible concentrations of specific radionuclides and mixtures of radionuclides in air (RCG_a) and water (RCG_w) for individuals in the general population.(US81a) In addition to restricting specific radionuclides, the guides restricted the concentration of radionuclides in a mixture such that the sum of the ratios of each radionuclide concentration to the appropriate concentration guide would not exceed a value of one. The guides further stated that a radionuclide might be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture to the concentration guide for that radionuclide did not exceed one tenth and (b) the sum of such ratios for all radionuclides considered as not present in the mixture did not exceed one fourth.

During 1987, average specific radionuclide concentrations in air and water for the Rocky Flats Plant were all less than one tenth of the appropriate Derived Concentration Guides for specific radionuclides. The sum of the ratios of those average concentrations to their respective DCGs was less than one fourth for all air and water sampling locations. Applying the same methodology for reporting mixtures under the DCG concept as was used with RCGs, the measured concentrations in the tables have been compared to the concentration guides for specific radionuclides rather than to the guide for mixtures.

The fractions of ingested radionuclides that are absorbed in the gastro-intestinal tract and the lung clearance classes for inhaled radionuclides were chosen to yield the most restrictive DCGs for comparisons in this report. Throughout this report, where a radionuclide concentration is expressed as the cumulative measurement of more than one isotope, the stated DCG used for comparison represents the most restrictive DCG for that grouping of isotopes. Plutonium concentrations measured at Rocky Flats Plant represent the alpha radioactivity from plutonium isotopes 239 and 240, which constitute over 97 percent of the alpha radioactivity in plutonium handled at the plant.

Reported uranium concentrations are the cumulative alpha activity from uranium-233, -234, and -238. Components containing fully enriched uranium are handled at the Rocky Flats Plant. Depleted uranium metal is fabricated and also is handled as process waste material. Uranium-235 is the major isotope by weight (93 percent) in fully enriched uranium; however, uranium-234 accounts for approximately 97 percent of the alpha activity of fully enriched uranium. In depleted uranium, the combined alpha activity from uranium-234 and -238 accounts for approximately 99 percent of the total alpha activity. The uranium DCGs used in this report for air and water are those for uranium-233, -234, and uranium-238, which are the most restrictive.

Environmental uranium concentrations can be measured by a variety of laboratory techniques. Nonradiological techniques yield concentration units of mass per unit volume such as $\mu g/m^3$ and $\mu g/\ell$. The uranium concentrations given in this report were derived by measuring radioactivity from alpha-emitting uranium isotopes and are expressed in terms of activity units per unit volume. Rocky Flats Plant data include measurements of depleted uranium, fully enriched uranium, and natural uranium.

Conversion factors for specific types of uranium can be used to compare the data in this report to data from other facilities and agencies that are given in units of mass per unit volume; however, the resulting approximations will not have the same assurance of accuracy as that for the original measured values. Uranium in effluent air from plant buildings is primarily depleted uranium. The conversion factor for these data is 2.6×10^6 g/Ci. Natural uranium is the predominant form found in water. The conversion factor for water data is 1.5×10^6 g/Ci.

The applicable EPA standard for beryllium (a nonradioactive material) in airborne effluents from plant buildings is 10 grams per stationary source in a 24-hour time period.(US78) For ambient air, the calculated DCG for plutonium-239 and -240 for members of the public is 20×10^{-15} μCi/mℓ (7.4×10^{-4} Bq/m^3).

The calculated americium-241 DCG in waterborne effluents for members of the public is 60×10^{-9} μCi/mℓ (2.2 Bq/ℓ). The comparable DCG for plutonium-239, -240 in water is 300×10^{-9} μCi/mℓ (11 Bq/ℓ). The most restrictive calculated DCG for uranium-233, -234, and -238 in water is 500×10^{-9} μCi/mℓ (19 Bq/ℓ), which is the DCG for uranium-233. In waterborne effluents available to members of the public, the calculated DCG for tritium is $2{,}000{,}000 \times 10^{-9}$ μCi/mℓ (74,000 Bq/ℓ).

In 1976, the EPA promulated regulations for radionuclides in drinking water.(US76a) These regulations were effective on June 24, 1977, along with primary drinking water regulations for microbiological, chemical, and physical contaminants. The intent of the Safe Drinking Water Act was to ensure that each state has primary responsibility for maintaining drinking water quality. To comply with these requirements, the Colorado State Board of Health modified exisiting State drinking water standards to include radionuclides.(Co77, Co81) Two of the community drinking water standards

are of interest in this report. The State standard for gross-alpha activity (including radium-226 but excluding radon and uranium) in community water systems is a maximum of 15 pCi/ℓ or 15 X 10^{-9} μCi/mℓ (5.6 X 10^{-1} Bq/ℓ). Americium and plutonium, which are alpha-emitting radionuclides, are included in this limit. The limit for tritium in drinking water is 20,000 pCi/ℓ or 20,000 X 10^{-9} μCi/mℓ (740 Bq/ℓ).

The Rocky Flats Plant NPDES permit, which the EPA reissued in 1984 to DOE, established sanitary effluent limitations on discharge from Pond B-3 (sewage effluent), limitations for nitrate and pH in the discharge from Pond A-3 in the Walnut Creek drainage, limitations on discharge from the reverse osmosis pilot plant, on Woman Creek drainage, limitations on discharge from the reverse osmosis plant, and control of sediment release during discharge from Ponds A-4, B-5, and C-2.

In addition to evaluating compliance with all relevant guides, limits, and standards, the Health, Safety and Environment Department assists operating groups in adhering to the DOE policy that ". . .operations shall be conducted in a manner to assure that radiation exposure to individuals and population groups is limited to the lowest levels technically and economically practicable."(US81a)

TABLE A-1. Radiation Protection Standards for the Public for Department of Energy Facilities(Va85)

	Effective Dose Equivalent (mrem/year)
From All Pathways:	
Occasional Exposures–	500
Prolonged Exposures (> 5 years)–	100
	Dose Equivalent (mrem/year)
Individual Organ–	5,000
	Dose Equivalent (mrem/year)
Air Pathway Only:	
Whole Body–	25
Any Organ–	75

2.2 Bq/ℓ

TABLE A-2. Applicable Standards for Radioactive and Nonradioactive Materials

Legend

μCi	=	microcuries	40 CFR 61	=	Code of Federal Regulations National Emission Standards for Hazardous Air Pollutants (USEPA)
m^3	=	cubic meters			
mℓ	=	milliliters			
mg/ℓ	=	milligrams per liter			
SU	=	standard units	DOE	=	Department of Engery
NA	=	not applicable	NPDES	=	National Pollutant Discharge Elimination System
g	=	grams			
			CDH	=	Colorado Department of Health

Parameter	Applicable Guides and Standards	Reference
Airborne Effluents		
Plutonium-239, -240	NA	NA
Uranium-233, -234, -238	NA	NA
Tritium	NA	NA
Beryllium	<10.0 g/day	40 CFR 61.32(a)
Ambient Air		
Plutonium-239, -240	20.0×10^{-15} μCi/mℓ	Calculated[a]
Waterborne Effluents (Radioactive)		
Plutonium-239, -240	300×10^{-9} μCi/mℓ	Calculated[a]
Uranium-233, -234, -238	500×10^{-9} μCi/mℓ	Calculated[a]
Americium-241	60×10^{-9} μCi/mℓ	Calculated[a]
Tritium	$2{,}000{,}000 \times 10^{-9}$ μCi/mℓ	Calculated[a]

Parameter	Discharge Limitations[b] Monthly Average	Weekly Average	Daily Maximum	Reference
Effluent Water Samples (Nonradioactive)				
pH		6.0-9.0 SU		NPDES Permit
Nitrates as N	10 mg/ℓ	20 mg/ℓ	NA	NPDES Permit
Total Phosphorus	8 mg/ℓ	NA	12 mg/ℓ	NPDES Permit
Biochemical Oxygen Demand, 5-Day	10 mg/ℓ	NA	25 mg/ℓ	NPDES Permit
Suspended Solids	30 mg/ℓ	45 mg/ℓ	NA	NPDES Permit
Total Chromium	0.05 mg/ℓ	NA	0.1 mg/ℓ	NPDES Permit
Residual Chlorine	NA	NA	0.5 mg/ℓ	NPDES Permit
Oil and Grease	NA	NA	Visual	NPDES Permit
Fecal Coliform – No./100 mℓ	200	400	NA	NPDES Permit
Total Organic Carbon	22 mg/ℓ	NA	30 mg/ℓ	NPDES Permit

a. Calculated on the basis of DOE August 5, 1985, memorandum using DOE dose limit of 0.1 rem/yr to members of the public from all pathways, dose conversion factors given in the memorandum, and intake rates of 2.66×10^2 mℓ/s for air and 2×10^3 mℓ/day for water.(St86)

b. These limitations are presented as indicators of the types of parameters and associated concentration limits required by the NPDES permit. Details of these requirements specific to each discharge location are given in the referenced document.(US84a) The daily and monthly limitations indicated cannot be correlated with the annual water quality data summarized in Table 11.

APPENDIX B
QUALITY CONTROL

A Quality Program Plan and a Quality Control Program Plan have been developed for the Environmental Management (EM) and the Health/Environment Analytical Laboratory (H/EL) Sections, respectively. Independent audits of these plans, coupled with EM's internal environmental audit and controls procedures, ensure that necessary quality assurance and quality control elements exist for a comprehensive environmental monitoring program.

The Quality Program Plan developed by Environmental Management provides controls for assurance that:

- Current operating procedures exist for all phases of EM operations and that these procedures are implemented as written.
- Appropriate approvals are obtained prior to program initiation or change.
- The equipment used in sample collection and data analysis is appropriate to the assigned function and is operating as required.
- Accurate documentation exists for all programs, procedures, and actions.
- All variances from procedures or equipment use and performance are documented and explained with an assessment.
- Appropriate guidelines and standards for environmental monitoring are identified, and documentation of compliance is provided on a routine basis to Rocky Flats Plant management, Department of Energy (DOE), and state and federal regulatory agencies.

The EM Quality Program Plan establishes control points and delineates responsibilities for specific categories of activities; provides an information base from which procedures can be developed, updated, and/or implemented; establishes a state of emergency preparedness in its contingency plans; and provides documentation to comply with rules and regulations of federal, state, and local regulatory agencies.

The plan includes quality assurance flow charts and quality matrices that illustrate activity networks and corresponding quality elements of each responsibility area. A complete listing of activities and responsibilities is also included in the Plan.

To ensure data reliability, the H/EL Quality Control Program Plan outlines the quality control methods used in all phases of laboratory operations.

This quality control program includes the following elements:

- Development, evaluation, improvement, modification, and documentation of analytical procedures.
- Scheduled instrument calibration, control charting, and preventive maintenance.
- Participation in interlaboratory quality comparison programs.
- Intralaboratory quality control programs.

All sample batches scheduled for analysis by the H/EL Central Receiving Laboratory contain an average of 10 percent control samples. The controls consist of analytical blanks prepared in-house and standards prepared by the Rocky Flats Chemistry Standards Laboratory.

An analysis or group of analyses may be rejected and the sample or samples scheduled for reanalysis for one or more of the following reasons:

1. The chemical recovery is less than 10 percent or greater than 100 percent.
2. The analytical blanks in the analysis batch are out of acceptable range.
3. The standards in the analysis batch are not within acceptable limits of error.
4. The alpha energy spectrum is not acceptable because of the following:

a. extra and/or unidentified peaks.

b. excess noise in background areas.

c. poor resolution of peaks.

5. The chemist in charge of the laboratory believes there is reason to suspect the analysis.

Any unusual condition affecting the results, which is noted either during sample collection or analysis, is reported to Environmental Management.

Table B-1 is a summary of H/EL participation in the Rocky Flats Chemistry Standards Laboratory Bioassay and Environmental Measurements Program for 1987.

The H/EL participates in the EPA Environmental Monitoring Systems Laboratory (EMSL) and the DOE Environmental Measurements Laboratory Crosscheck Programs. Tables B-2 and B-3 summarize the H/EL participation in this program.

TABLE B-1. Health/Environment Analytical Laboratory Environmental Measurements Control Program Data[a]
(January Through December 1987)

Attribute	Matrix	Method	Standard Range		Normal Sample Range		Annual Relative[b] Error Percent	Range of Relative Error Percent	Total Control Analyses
Pu-239, -240	Water	Alpha Spectral	1.2-35	d/m/ℓ	0-3	d/m/ℓ	- 1	-33 to + 89	58
Am-241	Water	Alpha Spectral	0.7-21	d/m/ℓ	0-3	d/m/ℓ	23	-99 to + 45	51
U-238, -234, -235	Water	Alpha Spectral	3-90	d/m/ℓ	0-30	d/m/ℓ	-13	+ 2 to +134	79
H-3	Water	Liquid Scintillation	14,000-420,000	d/m/ℓ	0-9990	d/m/ℓ	-11	-26 to - 19	38
Pu-239, -240	Effluent Filters	Alpha Spectral	4-120	d/m/f	0-30	d/m/f	- 4	-12 to + 10	117
Am-241	Effluent Filters	Alpha Spectral	3-90	d/m/f	0-4	d/m/f	10	-52 to + 14	96
U-238, -234, -235	Effluent Filters	Alpha Spectral	10-300	d/m/f	0-30	d/m/f	- 3	-26 to - 4	103
Be[c]	Effluent Filters	Atomic Absorption	0.3-10	µg/f	0-5	µg/f	- 1	-97 to +196	79
Be	Workplace Filter	Atomic Absorption	0.3-10	µg/f	0-20	µg/f	- 3	-80 to + 96	1291
Pu-239, -240	Ambient Filter	Alpha Spectral	2-45	d/m/f	0-50	d/m/f	- 7	-66 to + 15	46

a. The Bioassay-Environmental Measurements Control System was discontinued in October 1987 and replaced by the Interactive Measurements Evaluation Control System. Results from these two measurement control systems are combined in this summary for the January through December 1987 period.

b. The mean of the ratio of the 12-month deviations between observed and standard value to standard value in percent; the relative error for control measurements is often called the coefficient of variation where the dispersion of data (in this case, the mean difference between measured and standard values) is divided by the average standard value submitted. This term is inclusive of all random and systematic error in the standards, analytical chemistry, and measurement process for a given nuclide, matrix, and procedure.

c. Analyzed by 881 General Laboratory.

TABLE B-2. Health/Environment Analytical Laboratory Participation in the EPA Environmental Monitoring Systems Laboratory Crosscheck Program During 1987

Isotope Reported	Matrix	Method	Number of Analyses	Number of Acceptable Analyses[a]	Annual Relative Error Percent[b]	Range of Relative Error Percent
Gross Alpha	Filter	Alpha Spectral	2	2	-39.9	-76.7 to -3.1
Gross Beta	Filter	Gas Proportional	2	1	-12.5	-28.9 to 4.8
H-3	Water	Beta Liquid Scintillation	3	0	-22.9	-26.4 to 19.2
Co-60	Water	Gamma Spectral	4	3	47.8	-15.3 to 158.3[c]
Cs-134	Water	Gamma Spectral	4	3	36.2	-34.4 to 160.0[c]
Cs-137	Water	Gamma Spectral	4	2	54.7	-29.1 to 228.7[c]
Cs-137	Filter	Gamma Spectral	1	0	213.0	NA[c,d]
Ru-106	Water	Gamma Spectral	3	1	-5.6	-36.7 to 19.7
Pu-239	Water	Alpha Spectral	2	2	0.4	-2.4 to 3.2
U (nat.)	Water	Alpha Spectral	3	3	-20.5	-60.0 to 8.8

a. "Acceptable analyses" are those analyses for which the observed value was within ± 3 standard deviations of the standard value.

b. The mean of the ratio of the 12-month deviations between observed and standard value to standard value in percent; the relative error for control measurements is often called the coefficient of variation where the dispersion of data (in this case, the mean difference between measured and standard values) is divided by the average standard value submitted. This term is inclusive of all random and systematic error in the standards, analytical chemistry, and measurement process for a given nuclide, matrix, and procedure.

c. The upper value in the range of relative error percent was attributed to an erroneous radioactivity value assigned to a calibration standard.

d. NA = Not applicable.

TABLE B-3. Health/Environment Analytical Laboratory Participation in the DOE Environmental Monitoring Systems Laboratory Crosscheck Program During 1987

Isotope Reported	Matrix	Method	Number of Analyses	Mean of Ratio Reported/Standard Value	Range of Ratios
Mn-54	Water	Gamma Spectral	1	0.81	NA
Co-60	Water	Gamma Spectral	1	0.76	NA
Cs-137	Water	Gamma Spectral	1	0.77	NA
Pu-239	Filter	Alpha Spectral	2	0.93	0.92 to 0.94
Am-241	Filter	Alpha Spectral	2	1.12	1.11 to 1.12
U (nat.)	Filter	Alpha Spectral	2	0.42	0.41 to 0.43
Pu-239	Soil	Alpha Spectral	1	2.18	NA
U (nat.)	Soil	Alpha Spectral	1	1.00	NA
Pu-239	Water	Alpha Spectral	1	0.64	NA
Am-241	Water	Alpha Spectral	1	1.07	NA
U (nat.)	Water	Alpha Spectral	1	0.74	NA

APPENDIX C
ANALYTICAL PROCEDURES

The Health/Environment Analytical Laboratory (H/EL) routinely performs the following analyses on environmental and effluent samples:

1. Total Air Filter Counting (Pu specific alpha)
2. Tennelec Air Filter Counting (Gross alpha & gross beta)
3. Gamma Spectral Analysis
4. Alpha Spectral Analysis (Pu-239, -238, Am-241, U-238, -233, -234)
5. Beta Liquid Scintillation (Tritium)
6. N,N-Diethyl-p-phenylenediamine (DPD) (Chlorine)
7. Bacteria
8. Atomic Absorption (Beryllium)

Procedures for these analyses are described in the H/EL Procedures and Practices Manual.(Wi82) The procedures for bacteria and chlorine analyses were developed following Environmental Protection Agency (EPA) guidelines. Soil procedures were developed following specifications set forth in "Measurements of Radionuclides in the Environment, Sampling and Analysis of Plutonium in Soil," NRC Reg. Guide 4.5. All new procedures and changes to existing procedures must be thoroughly tested, documented, and approved in writing by the Manager of H/EL before being implemented. Environmental Management is notified of any major changes that could affect analytical results. All procedures are reviewed annually for consistency with state-of-the-art techniques, or at any time an analytical problem is suspected. Copies of all procedures are kept on file in the office of the Manager of H/EL.

The following is a general outline of the analytical procedures followed by the laboratories.

Samples received for air filter screening are counted approximately 24 and 48 hours after collection. Samples exceeding the limits set by Environmental Management are recounted. If the total long-lived alpha concentration for a screened filter exceeds the EM action limits, the filter is directed for individual specific isotope analysis and/or followup investigation to determine the cause and any needed corrective action.

All water samples, except those scheduled for tritium analysis, are poured into one-liter Marinelli® containers and sealed before delivery to the gamma counting area. Routine water samples are counted for approximately twelve hours. Samples requiring a lower detection limit are counted from 16 to 72 hours.

Soil samples scheduled for gamma spectral analysis are dried, sieved through a ten-mesh sieve, weighed, and the fine portion is ball-milled. The fine portion is then placed in a 500-mℓ Marinelli® container and counted for at least 16 hours.

All samples scheduled for alpha spectral analysis are analyzed in a similar manner regardless of matrix. Prior to dissolution, a known quantity of nonindigenous radioactive tracer is added to each sample. The tracer is used to determine the chemical recovery for the analysis. Tracers used include Pu-236, Pu-242, U-232, U-236, Am-243, and Cm-244. The type and activity level of the tracer used depends on the type and projected activity level of the sample to be analyzed. All refractory or intractable actinides are dissolved by vigorous acid treatment using oxidizing and complexing acids.

After samples are dissolved, the radioisotopes of concern are separated from each other and from the matrix material by various solvent extraction and ion exchange techniques. The purified radioisotopes are electrodeposited onto stainless steel discs. These discs are alpha counted for a minimum of 16 hours. If a lower minimum detection limit is required samples may be counted from 72 to 168 hours depending upon the need. Samples that exhibit a chemical recovery of less than 10 percent or greater than 110 percent are automatically scheduled for reanalysis.

Tritium analyses are routinely performed on specified environmental water samples as well as stack effluent samples. Five milliliters of the samples are combined with 17 milliliters of liquid scintillation cocktail mixture. Environmental samples are counted for 60 minutes and airborne effluent samples are counted for 10 minutes.

The General Laboratory routinely performs the following analyses for environmental monitoring of plant effluent streams, process wastes, and soil residues:

1. Dissolved metallic elements including tests for 31 cations by emission spectroscopic techniques and 17 elements by atomic absorption techniques (including beryllium in airborne effluent sample filters).

2. Oxygen demand tests, including total organic carbon, dissolved oxygen, chemical oxygen demand, and biological oxygen demand (5 day incubation).

3. Nutrient tests including free ammonia and amines, ortho and total phosphate phosphorus, nitrate and nitrate anions, Kjeldahl nitrogen, and total nitrogen.

4. Physical tests, including pH, conductivity, color, total dissolved solids, suspended solids, turbidity, and specific gravity.

5. Soap residues (as alkyl sulfonate).

6. Oil and grease residues, by extraction and infrared or gravimetric detection, and by visual observation.

7. Specific chemical property or element, including total hardness (as calcium carbonate), alkalinity (as hydroxide, bicarbonate, or carbonate), chloride, fluoride, cyanide, sulfate, and hexavalent chromium.

8. Radioactive species, including gross alpha and beta by gas proportional detection; tritium by liquid scintillation detection; cesium-137 and total radiostrontium by gravimetric separation followed by gas proportional detection. Isotopes of plutonium, americium, thorium, uranium, neptunium, and curium are determined by ion exchange and liquid extraction techniques followed by alpha pulse height analysis.

9. Organic toxic species, including phenol, polychlorinated-biphenyls, and total organic halogen.

Procedures for these analyses were developed by the General Laboratory professional technical staff. Procedures were adopted from EPA-approved sources or from other recognized authoritative publications where EPA-approved procedures were not available. Laboratory operations procedures are documented in a standard format, approved by the manager of the Rocky Flats Analytical Laboratories, and distributed to a controlled distribution list to assure that proper testing and approval is performed before changes are adopted. The General Laboratory Quality Assurance Plan requires annual review of procedures for consistency with state-of-the-art techniques and compliance of laboratory practice with written procedures. In addition, a review is performed whenever an analytical problem is indicated.

The following is a general outline of the analysis procedures followed by the General Laboratory:

All water samples which are analyzed for radioactive materials - except those scheduled for tritium analysis - are acidified immediately upon collection.

Liquid samples received for gross alpha and beta screening are evaporated directly onto planchets for gas proportional counting within 24 hours of collection. When activities exceeding the action guidelines set by Environmental Management (EM) are observed, notification to EM is made, and reanalysis is begun immediately for verification.

For some liquids such as machine oils, a specified volume is evaporated, ashed, and the salt residue is taken up in nitric acid for deposit onto the counting planchet. A correction factor is determined for each sample to account for self-absorption effects.

Water samples to be tested for chemical and physical parameters are analyzed within 24 hours of collection, or they are preserved by refrigeration, freezing, or addition of a chemical preservative when required. The tests performed include gravimetric, titrametric, colorimetric, chromatographic, or electroanalytical methods, following procedures specified in the 15th edition of Standard Methods for the Examination of Water and Waste Water, EPA-600/4-79-020, or other authoritative publications.

Water samples to be analyzed for dissolved metallic ions are filtered through a 0.45 micrometer filter and evaporated onto a graphite electrode for emission spectrographic analysis. Selected elements are determined for sample solutions by atomic absorption methods after appropriate chemical treatment to prepare the proper analysis matrix.

Organic toxic species are determined by chromatography, following extraction into an appropriate organic solvent, using electron capture detection. Some organics, such as phenol, are determined by developing a chromaphoric complex and measuring light absorption at a specific wavelength with a spectrophotometer. Measuring occurs after extraction into an appropriate solvent phase.

Tritium is determined by intimate mixing of five milliliters of aqueous sample (or of water that has equilibrated with the sample for a predetermined time to ensure exchange) with 27 milliliters of scintillation cocktail. The mixture is counted for 20 minutes in a scintillation well, and a correction factor is applied to account for quenching effects determined in situ for each sample.

Cesium and strontium isotopes are radiochemically separated from the sample matrix using precipitation techniques. Cesium and strontium isotopes are deposited on planchets with a carrier element for alpha or beta gas proportional counting.

APPENDIX D
DETECTION LIMITS AND ERROR TERM PROPAGATION

The Rocky Flats Health/Environment Analytical Laboratory (H/EL) have adopted the following definition for detection limit, as given by Harley.(Ha72)

> "The smallest amount of sample activity using a given measurement process (i.e., chemical procedure and detector) that will yield a net count for which there is confidence at a predetermined level that activity is present."

The minimum detectable amount (MDA) is the term used to describe the detection limit and is defined as the smallest amount of an analyzed material in a sample that will be detected with a β probability of non-detection (Type II error), while accepting an α probability of erroneously detecting that material in an appropriate blank sample (Type I error). At the 95% confidence level, both α and β are equal to 0.05.

Based on the approach presented in draft ANSI standard N13.30 "Performance Criteria for Radiobioassay,"(He85) the formulation of the MDA for radioactive analyses is:

$$MDA = \frac{4.65\, S_B + 3/(T_S E_S Y)}{aV}$$

where S_B = standard deviation of the population of appropriate blank values (d/m)

T_S = sample count time (m)

E_S = absolute detection efficiency of the sample detector

Y = chemical recovery for the sample

a = conversion factor (d/m per unit activity)

(a = 2.22 d/m/pCi when MDA is in units of pCi and

$a = 2.22 \times 10^6$ d/m/μCi when MDA is in units of μCi.)

V = sample volume or weight

(V=1 if the MDA per sample is desired.)

The major component of the MDA equation is the variability of the blanks.

Table D-1 shows the various formulae used for alpha data reduction during 1987.

Table D-2 shows the typical MDA values for the various analyses performed by the H/EL and by the General Laboratories. These values are based on the average sample volume, typical detector efficiency, detector background, count time, and chemical recovery. MDA values calculated for individual analyses may vary significantly depending on actual sample volume, chemical recovery, and analytical blank used.

For nonradioactive parameters, various means are used to estimate a minimum detectable amount depending on the parameter measured. The minimum detectable amount for beryllium in effluent air - analyzed using flameless atomic absorption spectroscopy - is based on a sample blank absorbance reading. Total chromium in effluent water samples undergoes a four-fold concentration of the received sample prior to its analysis using flame atomic absorption spectroscopy. Its approximate minimum detectable amount is based on a net sample absorbance reading of 0.010.

The parameters of nitrate as N, total phosphorous, suspended solids, oil and grease, and total organic carbon all have minimum detectable amounts that are determined by procedural methods found in EPA-600 "Methods for Chemical Analysis of Water and Wastewater."(US79) The parameters of pH and biochemical oxygen demand have minimum detectable amounts that are determined by the minimal readout capability of the instrumentation that is used.

The minimum detectable amount for residual chlorine is determined by the procedure found in a publication by Hach Co., "DPD Method for Chlorine."(Ha83) For fecal coliform count, the minimum detectable amount is calculated as 4.65 times the standard deviation of the blank value from the millipore filter.

TABLE D-1. Formulae for Activity and Uncertainty Calculations for the Alpha Spectral Analysis Systems

Non-Blank Corrected Sample Uncertainty*

$$a_{sj} = A_{si}\left[\frac{\frac{C_{si}}{T_s^2}+\frac{C_{Bi}}{T_B^2}}{\left(\frac{C_{si}}{T_s}-\frac{C_{Bi}}{T_B}\right)^2}+\frac{\frac{C_{sj}}{T_s^2}+\frac{C_{Bj}}{T_B^2}}{\left(\frac{C_{sj}}{T_s}-\frac{C_{Bj}}{T_B}\right)^2}\right]^{1/2}$$

Blank Corrected Sample Uncertainty

$$b_{si} = (a_{si}^2 + a_{ri}^2)^{1/2}$$

Non-Blank Corrected Sample Activity

$$A_{si} = \left[\frac{\frac{C_{si}}{T_s}-\frac{C_{Bi}}{T_B}}{\frac{C_{sj}}{T_s}-\frac{C_{Bj}}{T_B}}\right]\cdot\frac{D_{sj}}{V\cdot 2.22}$$

Blank Corrected Sample Activity

$$B_{si} = A_{si} - A_{ri}$$

*Corrected from 1984 report.

(continued)

TABLE D-1. (Concluded)

Legend

A_{ri} = Non-blank corrected activity of laboratory reagent blank for isotope i expressed as picocuries (pCi) per unit volume.

a_{ri} = Non-blank corrected uncertainty of laboratory reagent blank expressed as pCi per unit volume.

A_{si} = Sample activity for isotope i expressed as pCi per unit volume.

a_{si} = Sample activity uncertainty expressed as pCi per unit volume.

B_{si} = Blank corrected sample activity for isotope i expressed as pCi per unit volume.

b_{si} = Blank corrected sample uncertainty expressed as pCi per unit volume.

D_{sj} = Activity (dpm) of internal standard isotope j added to sample.

C_{si} = Sample gross counts for isotope i.

C_{sj} = Sample gross counts for internal standard isotope j.

C_{Bi} = Detector background gross counts for isotope i.

C_{Bj} = Detector background gross counts for internal standard isotope j.

T_s = Sample count time expressed in minutes.

T_B = Detector background count time expressed in minutes.

V = Sample unit volume or sample unit weight.

TABLE D-2. Detection Limits for Radioactive and Nonradioactive Materials

Legend

μCi	= microcuries	pCi	= picocuries
μg	= micrograms	mg/ℓ	= milligrams per liter
m^3	= cubic meters	SU	= standard units
mℓ	= milliliters		

Parameter	Minimum Detectable Amount (per sample)	Approximate Sample Volume Analyzed[a]	Minimum Detectable Amount (per unit volume or mass)
Airborne Effluent Samples			
Plutonium 239, 240	7.4×10^{-8} μCi	7,340 m^3[b]	0.010×10^{-15} μCi/mℓ
Uranium 233, 234, 238	3.9×10^{-7} μCi	7,340 m^3[b]	0.053×10^{-15} μCi/mℓ
Tritium	9.0×10^{-6} μCi	1.4 m^3	$6{,}400 \times 10^{-15}$ μCi/mℓ
Beryllium	2.5×10^{-1} μg	7,340 m^3[b]	5×10^{-5} μg/m^3
Ambient Air Samples			
Plutonium 239, 240	9.9×10^{-8} μCi	29,000 m^3[c]	0.0034×10^{-15} μCi/mℓ
Effluent Water Samples (Radioactive)			
Plutonium 239, 240	5.9×10^{-8} μCi	5,000 mℓ	0.012×10^{-9} μCi/mℓ[c]
Uranium 233, 234, 238	5.7×10^{-8} μCi	1,000 mℓ	0.057×10^{-9} μCi/mℓ
Americium 241	6.3×10^{-8} μCi	5,000 mℓ	0.013×10^{-9} μCi/mℓ[c]
Tritium	1.0×10^{-5} μCi	5 mℓ	$2{,}000 \times 10^{-9}$ μCi/mℓ
Soil Samples (Radioactive)			
Plutonium 239, 240	3.0×10^{-7} μCi	10 g	3.0×10^{-8} μCi/g
Effluent Water Samples (Nonradioactive)			
pH		100 mℓ	0-14 SU
Nitrate as N		10 mℓ	0.2 mg/ℓ
Total Phosphorus		50 mℓ	0.2 mg/ℓ
Biochemical Oxygen Demand, 5-Day		300 mℓ	5.0 mg/ℓ
Suspended Solids		100 mℓ	1.0 mg/ℓ
Total Chromium		100 mℓ	0.05 mg/ℓ
Residual Chlorine		10 mℓ	0.1 mg/ℓ
Oil and Grease		1,000 mℓ	0.5 mg/ℓ
Fecal Coliform Count		10-100 mℓ	43 organisms/100 mℓ
Total Organic Carbon		5 mℓ	1.0 mg/ℓ

a. Volume analyzed is usually an aliquoted fraction of the total sample volume collected.
b. Monthly composite.
c. Composite of two bi-weekly samples.

APPENDIX E

REPORTING OF MINIMUM DETECTABLE CONCENTRATION AND ERROR TERMS

Throughout the section entitled "Monitoring Data: Collection, Analyses, and Evaluation" in this report, some of the concentrations that are measured at or below the minimum detectable concentration (MDC) are assigned the MDC value. The less-than symbol (<) indicates MDC values and calculated values that include one or more MDCs.

The plutonium, uranium, americium, and beryllium measured concentrations are reported. These reported concentrations include values that are less than the corresponding calculated MDCs and in some cases, values less than zero. Negative values result when the measured value for a laboratory reagent blank is subtracted from an analytical result that was measured as a smaller value than the reagent blank. These resulting negative values are included in any arithmetic calculations on the data set.

Error terms in the form of a ± b are included with some of the data. For a single sample, "a" is the reagent-blank corrected value; for multiple samples it represents the average value (arithmetic mean). The error term "b" accounts for the propagated statistical counting uncertainty for the sample and the associated reagent blanks at the 95 percent confidence level. These error terms represent a minimum estimate of error for the data. Other analytical and sampling errors are being investigated for future incorporation into an all-inclusive error term for each value.

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